



CERTIFICATE OF TRANSLATION

I, Chimoto Saito, at Koei-Palace 202, 14-10, Makuharihongo 1-chome, Hanamigawa-ku, Chiba-shi, Chiba 262-0033 Japan, do hereby certify that to the best of my knowledge and belief the attached English translation is a true and accurate translation, made by me, familiar with both Japanese and English language, and for which I accept responsibility, of the PCT international application No. PCT/JP99/02673, filed in Japan on May 21, 1999 in the name(s) DIGITAL SUBSCRIBER LINE TRANSMISSION METHOD, APPARATUS AND SYSTEM.

February 21, 2006
Date

Chimoto Saito
Chimoto Saito

THIS PAGE BLANK (USPTO)

PCT REQUEST

9902040

Draft (NOT for submission) - printed on 20.09.2000 09:08:00 AM

0	For receiving Office use only	
0-1	International Application No.	
0-2	International Filing Date	
0-3	Name of receiving Office and "PCT International Application"	
0-4	Form - PCT/RO/101 PCT Request	
0-4-1	Prepared using	PCT-EASY Version 2.83 (updated 01.03.1999)
0-5	Petition The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty	
0-6	Receiving Office (specified by the applicant)	Japanese Patent Office (RO/JP)
0-7	Applicant's or agent's file reference	9902040
I	Title of invention	DIGITAL SUBSCRIBER LINE TRANSMISSION METHOD, APPARATUS AND SYSTEM
II	Applicant	
II-1	This person is:	applicant only
II-2	Applicant for	all designated States except US
II-4	Name	FUJITSU LIMITED
II-5	Address:	1-1, Kamikodanaka 4-chome, Nakahara-ku, Kawasaki-shi, Kanagawa 211-8588 Japan
II-6	State of nationality	JP
II-7	State of residence	JP
II-8	Telephone No.	044-754-3034
II-9	Facsimile No.	044-754-3563
III-1	Applicant and/or inventor	
III-1-1	This person is:	applicant and inventor
III-1-2	Applicant for	US only
III-1-4	Name (LAST, First)	HASEGAWA, Kazutomo
III-1-5	Address:	c/o FUJITSU LIMITED, 1-1, Kamikodanaka 4-chome, Nakahara-ku, Kawasaki-shi, Kanagawa 211-8588 Japan
III-1-6	State of nationality	JP
III-1-7	State of residence	JP

PCT REQUEST

Draft (NOT for submission) - printed on 20.09.2000 09:08:00 AM

III-2	Applicant and/or inventor	
III-2-1	This person is:	applicant and inventor
III-2-2	Applicant for	US only
III-2-4	Name (LAST, First)	ASAHINA, Hidetake
III-2-5	Address:	c/o FUJITSU DIGITAL TECHNOLOGY LIMITED, 3-9, Shin-Yokohama 2-Chome, Kohoku-ku, Yokohama-shi, Kanagawa 222-0033 Japan
III-2-6	State of nationality	JP
III-2-7	State of residence	JP
III-3	Applicant and/or inventor	
III-3-1	This person is:	applicant and inventor
III-3-2	Applicant for	US only
III-3-4	Name (LAST, First)	MIYOSHI, Seiji
III-3-5	Address:	c/o FUJITSU LIMITED, 1-1, Kamikodanaka 4-chome, Nakahara-ku, Kawasaki-shi, Kanagawa 211-8588 Japan
III-3-6	State of nationality	JP
III-3-7	State of residence	JP
III-4	Applicant and/or inventor	
III-4-1	This person is:	applicant and inventor
III-4-2	Applicant for	US only
III-4-4	Name (LAST, First)	KOIZUMI, Nobukazu
III-4-5	Address:	c/o FUJITSU LIMITED, 1-1, Kamikodanaka 4-chome, Nakahara-ku, Kawasaki-shi, Kanagawa 211-8588 Japan
III-4-6	State of nationality	JP
III-4-7	State of residence	JP
III-5	Applicant and/or inventor	
III-5-1	This person is:	applicant and inventor
III-5-2	Applicant for	US only
III-5-4	Name (LAST, First)	AWATA, Yutaka
III-5-5	Address:	c/o FUJITSU DIGITAL TECHNOLOGY LIMITED, 3-9, Shin-Yokohama 2-Chome, Kohoku-ku, Yokohama-shi, Kanagawa 222-0033 Japan
III-5-6	State of nationality	JP
III-5-7	State of residence	JP

PCT REQUEST

9902040

Draft (NOT for submission) - printed on 20.09.2000 09:08:00 AM

IV-1	Agent or common representative; or address for correspondence The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as:	agent
IV-1-1	Name (LAST, First)	SAITO, Chimoto
IV-1-2	Address:	Saito Patent Office, Koei-Palace 202, 14-10, Makuharihongo 1-chome, Hanamigawa-ku, Chiba-shi, Chiba 262-0033 Japan
IV-1-3	Telephone No.	043-271-8176
IV-1-4	Facsimile No.	043-271-8318
IV-1-5	e-mail	saipat@mb.infoweb.ne.jp
V	Designation of States	
V-1	Regional Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	EP: AT BE CH&LI CY DE DK ES FI FR GB GR IE IT LU MC NL PT SE and any other State which is a Contracting State of the European Patent Convention and of the PCT
V-2	National Patent (other kinds of protection or treatment, if any, are specified between parentheses after the designation(s) concerned)	JP US
V-5	Precautionary Designation Statement In addition to the designations made under items V-1, V-2 and V-3, the applicant also makes under Rule 4.9(b) all designations which would be permitted under the PCT except any designation(s) of the State(s) indicated under item V-6 below. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit.	
V-6	Exclusion(s) from precautionary designations	NONE
VI	Priority claim	NONE
VII-1	International Searching Authority Chosen	Japanese Patent Office (JPO) (ISA/JP)

PCT REQUEST

9902040

Draft (NOT for submission) - printed on 20.09.2000 09:08:00 AM

VIII	Check list	number of sheets	electronic file(s) attached
VIII-1	Request	4	-
VIII-2	Description	38	-
VIII-3	Claims	3	-
VIII-4	Abstract	1	9902040.txt
VIII-5	Drawings	40	-
VIII-7	TOTAL	86	
	Accompanying items	paper document(s) attached	electronic file(s) attached
VIII-8	Fee calculation sheet	✓	-
VIII-10	Copy of general power of attorney	✓	-
VIII-16	PCT-EASY diskette	-	diskette
VIII-17	Other (specified):	patent revenue stamps	-
VIII-17	Other (specified):	certificate of payment of fee	-
VIII-18	Figure of the drawings which should accompany the abstract	1	
VIII-19	Language of filing of the international application	Japanese	
IX-1	Signature of applicant or agent		
IX-1-1	Name (LAST, First)	SAITO, Chimoto	

FOR RECEIVING OFFICE USE ONLY

10-1	Date of actual receipt of the purported international application	
10-2	Drawings:	
10-2-1	Received	
10-2-2	Not received	
10-3	Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application	
10-4	Date of timely receipt of the required corrections under PCT Article 11(2)	
10-5	International Searching Authority	ISA/JP
10-6	Transmittal of search copy delayed until search fee is paid	

FOR INTERNATIONAL BUREAU USE ONLY

11-1	Date of receipt of the record copy by the International Bureau	
------	--	--

SPECIFICATION

DIGITAL SUBSCRIBER LINE TRANSMISSION METHOD, APPARATUS AND SYSTEM

Technical Field

5 This invention relates to a digital subscriber line transmission method, and apparatus in which an existing telephone line (referred to as a "metallic line" below) is utilized as a high-speed data communication line. More particularly, the invention relates to a digital
10 subscriber line transmission method, and apparatus, which is based upon ISDN ping-pong transmission used in a periodic crosstalk noise environment.

Multimedia services such as the Internet have become widespread throughout society inclusive of the
15 ordinary home and there is increasing demand for early provision of economical, highly reliable digital subscriber line transmission systems and apparatus for utilizing these services.

Background Art

20 xDSL technology

xDSL (Digital Subscriber Line) is known as a technique that provides a digital subscriber line transmission system in which an existing telephone line is utilized as a high-speed data communication line.
25 xSDL is a transmission scheme that utilizes a telephone line and is one modulation/demodulation technique. xDSL is broadly divided into symmetric xDSL and asymmetric

xDSL. In symmetric xDSL, the upstream transmission rate from the subscriber residence (referred to as the "subscriber side" below) to the accommodating office (referred to as the "office side" below) and the downstream transmission rate from the office side to the subscriber side are symmetrical; in asymmetric xDSL, the upstream and downstream transmission rates are asymmetrical.

A typical example of asymmetric xDSL is ADSL (Asymmetric DSL) and typical examples of symmetric xDSL are HDSL (High-bit-rate DSL) and SHDSL (Single-pair High-bit-rate DSL). VDSL (Very high-bit-rate DSL) is available as an xDSL technique that is capable of being utilized as both an asymmetric and symmetric DSL. A modulation scheme such as DMT (Discrete Multitone) or CAP (Carrierless Amplitude Phase modulation), etc., is being used for each xDSL system. Examples of ITU-T recommendations concerning ADSL are G.dmt and G.lite, in which the downstream transmission rates are on the order of 6 Mbps and 1.5 Mbps, respectively. Both of these adopt DMT modulation as the modulation method.

DMT modulation

DMT modulation will be described taking G.dmt as an example. The description will relate only to modulation/demodulation in the downstream direction from the office side to the subscriber side.

With DMT modulation, as shown in Fig. 28, a frequency band of 1.104 MHz is divided into M(255)-

number of multicarriers #1 ~ #255 at intervals of Δf (= 4.3125 KHz). In training carried out before communication, the S/N ratios of the respective carriers #1 ~ #255 are measured and it is decided, depending upon
5 the S/N ratios, with which modulation method among 4-QAM, 16-QAM, 64-QAM, 128-QAM ... modulation methods data is to be transmitted in each carrier. For example, 4-QAM is assigned to a carrier having a small S/N ratio and 16-QAM, 64-QAM, 128-QAM ... are assigned
10 successively as the S/N ratio increases. It should be noted that 4-QAM is a modulation scheme in which two bits are transmitted at a time, 16-QAM a modulation scheme in which four bits are transmitted at a time, 64-QAM a modulation scheme in which six bits are
15 transmitted at a time, and 128-QAM a modulation scheme in which seven bits are transmitted at a time. Carriers #1 ~ #32 of the 255 carriers are used for the upstream direction from the subscriber side to the office side, and carriers #33 ~ #255 are used for the downstream
20 direction from the office side to the subscriber side.

Fig. 29 is a functional block diagram of a subscriber line transmission system based upon DMT modulation. Entered transmission data is stored in an amount conforming to the time for one symbol (= 1/4000
25 sec) in a serial-parallel conversion buffer (Serial-to-Parallel Buffer) 10. The stored data is divided into transmission bit counts per carrier decided and saved in a transmit bitmap 60 by training in advance. The

divided data is then input to an encoder 20. The encoder 20 converts each carrier corresponding to an input bit sequence to signal-point data (signal-point data on a constellation diagram) for performing quadrature amplitude modulation (QAM) and inputs the converted data to an Inverse Fast-Fourier Transform (IFFT) unit 30. The IFFT unit 30 applies quadrature amplitude modulation to each signal point by performing an IFFT operation and inputs the processed data to a parallel-to-serial conversion buffer (Parallel-to-Serial Buffer) 40. Here a total 32 samples, namely IFFT output samples 480 - 511, are duplicately attached to the beginning of a DMT signal as a cyclic prefix (the details of which will be described later). The parallel-to-serial conversion buffer 40 inputs 512 + 32 items of sample data to a D/A converter 50 successively in serial fashion. The D/A converter 50 converts the input digital data to an analog signal at a sampling frequency of 2.208 MHz and sends the analog signal to the subscriber side via a metallic line 70.

On the subscriber side, an A/D converter 80 converts the input analog signal to a 2.208-MHz digital signal and inputs the digital signal to a time domain equalizer (TEQ) 90. The latter applies processing to the input digital data in such a manner that inter-symbol interference (ISI) will fall within the cyclic prefix of 32 symbols, and inputs the processed data to a serial-to-parallel conversion buffer 100. The latter

stores one DMT symbol's worth of data and subsequently removes the cyclic prefix and inputs one DMT symbol's worth of data to a fast-Fourier transform (FFT) unit 110 simultaneously in parallel fashion. The FFT unit 110
5 implements a fast-Fourier transform and generates (demodulates) 255 signal points. A frequency domain equalizer (FEQ) 120 subjects the demodulated 255 items of signal-point data to inter-channel interference (ICI) compensation. A decoder 130 decodes the 255 items of
10 signal-point data in accordance with a receive bitmap 150, which has values identical with those of the transmit bitmap 60, and stores the data obtained by decoding in a parallel-to-serial conversion buffer 140. The data is subsequently read out of this buffer in the
15 form of a bit serial. This data constitutes the receive data.

Crosstalk from ISDN ping-pong transmission

ISDN ping-pong transmission which is referred to as time compression multiplexing separates transmit and
20 receive intervals in time-shared fashion (the total of one transmit interval and one receive interval is 2.5 ms) and makes the transmit and receive timings the same for all neighboring devices. With ISDN ping-pong transmission, 2B+D 144-kbps transmit data is demarcated
25 every 2.5 ms, compressed to 320 kbps by rate conversion and transmitted in the transmit interval. As a consequence, the frequency band of ISDN ping-pong transmission overlaps the frequency band of ADSL (or of

G.dmt), as shown in Fig. 30. Already existing telephone lines have a design optimized to a frequency band of about 200 Hz ~ 3.4 kHz, which is the frequency of the human voice. If ADSL and ISDN high-frequency signals are passed through such telephone lines, the fact that the lines are bundled together as shown in Fig. 31 allows the ISDN signal to leak into the ADSL telephone line and act as noise that interferes with the ADSL communication. Such noise is crosstalk noise. The ADSL transmission rate is limited by the level of this crosstalk noise.

Fig. 32 is a diagram useful in describing interference (crosstalk) from an ISDN line to an ADSL, in which (a) is for describing interference on an ADSL unit on the office side (ATU-C: ADSL Transceiver Unit at the Central office end) and (b) is for describing interference on an ADSL unit on the subscriber side (ATU-R: ADSL Transceiver Unit at the Central terminal end). In (a) of Fig. 32, the ADSL unit ATU-C on the office side is influenced by a large amount of noise when an OCU (Office Channel Unit) of the ISDN line is transmitting. This crosstalk noise is referred to as near-end crosstalk noise (NEXT). On the other hand, when a DSU (Digital Service Unit) is transmitting, this signal acts as noise by leaking into the ATU-C. This crosstalk noise is referred to as far-end crosstalk noise (FEXT). FEXT is remote with regard to the ATU-C, i.e., is noise from the remote end. In comparison with

NEXT, FEXT has a fairly low level.

In (b) of Fig. 32, the ADSL unit ATU-R on the subscriber side is influenced by a large amount of noise when a DSU of the ISDN line is transmitting. This
5 crosstalk noise is referred to as near-end crosstalk noise (NEXT). On the other hand, when an OCU is transmitting, this signal acts as far-end crosstalk noise (FEXT) by leaking into the ATU-R. In comparison with NEXT, FEXT has a fairly low level. Thus, in ADSL
10 communication, it is necessary to reduce the effects of NEXT.

As mentioned above, when an ISDN ping-pong transmission line is close to an ADSL, the ADSL is influenced by TCM crosstalk (Time compression
15 multiplexing crosstalk) from the ISDN ping-pong transmission line in a manner set forth below. In accordance with ISDN ping-pong transmission, the office side transmits the downstream data in the first-half cycles of 400 Hz in sync with an ISDN 400-Hz signal TTR
20 shown in Fig. 33, and the subscriber side transmits the upstream data after it receives the downstream data. The ADSL unit ATU-C on the office side, therefore, is influenced by near-end crosstalk (NEXT₁) from the ISDN in the first-half cycles of 400 Hz and is influenced by
25 far-end crosstalk (FEXT₁) from the upstream data of the ISDN on the subscriber side in the second-half cycles.

In a manner converse with respect to the office side, the ADSL unit ATU-R on the subscriber side is

influenced by FEXT₂ in the first-half cycles of 400 Hz
and is influenced by NEXT₂ in the second-half cycles.
The time intervals in which the effects of NEXT and FEXT
are received shall be referred to as NEXT and FEXT
5 intervals, respectively. Fig. 33 illustrates the NEXT
and FEXT intervals on the subscriber side.

Sliding-window method

A "sliding-window method" has been proposed in the
specification of Japanese Patent Application 10-144913
10 for the purpose of providing a digital subscriber line
transmission system that is capable of transmitting an
ADSL signal satisfactorily in an environment where there
is the above-described crosstalk from an ISDN ping-pong
transmission. The sliding-window method is such that in
15 the case of the downstream direction in which an ADSL
signal is transmitted from an ADSL unit (ATU-C) on the
office side to an ADSL unit (ATU-R) on the subscriber
side, the state of the ADSL signal transmitted by the
ADSL unit (ATU-C) on the office side in an environment
20 where there is crosstalk from an ISDN ping-pong
transmission is decided as set forth below. The method
includes dual bitmap and FEXT bitmap methods.

Specifically, if an ADSL symbol (DMT symbol) SB to
be transmitted falls entirely within the FEXT interval
25 on the subscriber side, as shown in Fig. 33, the ADSL
unit (ATU-C) on the office side transmits this symbol as
an inside symbol ISB by a sliding window SLW through a
high-density transmission. If a symbol SB to be

transmitted falls even partially within the NEXT interval on the subscriber side, the ADSL unit (ATU-C) on the office side transmits this symbol as an outside symbol OSB through a low-density transmission (dual
5 bitmap method). In the upstream direction also, the ADSL unit (ATU-R) on the subscriber side transmits the ADSL symbols upon dividing them into inside and outside symbols ISB, OSB, respectively, through a method similar to that employed in the downstream direction.

10 With the dual bitmap method, symbols are transmitted in low density even outside the sliding window SLW in the downstream direction. However, there is also the FEXT bitmap method, in which the ADSL unit (ATU-C) on the office side transmits only a pilot-tone
15 signal PLT, which is a tone-signal for timing synchronization, outside the sliding window SLW. In this case the ADSL unit (ATU-R) on the subscriber side makes no transmission outside the sliding window SLW in the upstream direction.

20 This Fig. 34 is a diagram showing the relationship between transmit/receive in the OCU of the ISDN and the ADSL symbols in the ADSL unit ATU-C on the office side. Fig. 34 illustrates ADSL symbols in both the dual bitmap and FEXT bitmap cases.

25 ·Bitmap creation

To support the dual bitmap method, it is required that two types of bitmaps, namely a bitmap for the inside symbols and a bitmap for the outside symbols, be

prepared at the time of training in both the transmit
bitmap unit 60 and receive bitmap unit 150 shown in Fig.
29. With the FEXT bitmap method, the outside-symbol
bitmap of these two types of bitmaps is unnecessary.

5 The bitmap which shows The bit count assigned to
each carrier is decided on the receiving side. That is,
the number of assigned bits for upstream signals is
decided on the office side and the number of assigned
bits for downstream signals is decided on the subscriber
10 side. When training is performed, the ADSL units on the
office and subscriber sides decide the bitmaps in
accordance with a protocol referred to as "B & G (bit &
gain)".

Fig. 35 is a diagram useful in describing the B & G
15 protocol for the upstream direction. (1) After the
ADSL units recognize each other at the time of training,
the ADSL unit ATU-R on the subscriber side sends several
frequency signals to the opposing ADSL unit ATU-C on the
office side, by way of example. (2) The ADSL unit ATU-
20 C on the office side measures the noise level and
received-signal level on a per-carrier basis and
calculates the S/N ratios. (3) The ADSL unit ATU-C on
the office side creates a bitmap based upon the S/N
ratios calculated and reports this bitmap and
25 transmission level to the ADSL unit ATU-R on the
subscriber side. (4) The ADSL unit ATU-R on the
subscriber side performs DMT modulation based upon the
reported bitmap and transmission-level information and

transmits the resulting data.

Fig. 36 is a block diagram of an arrangement in which S/N ratio is measured by the ADSL unit ATU-R on the subscriber side. Received data enters a demodulator 210, which outputs signal-point data on a per-carrier basis as demodulated data. Further, a reference 220 outputs carrier-by-carrier signal-point data that should be received originally. A difference ERROR develops between the signal-point data from the reference and the demodulated signal-point data, and the ERROR for each carrier is input to a selector 260.

An internal clock 230 of the device is frequency-divided to 400 Hz by a frequency divider 240 and the resulting signal is input to a phase discriminator 250. The 400-Hz signal has its phase matched beforehand to that of a 400-Hz signal (ISDN 400-Hz signal) on the office side by 400-Hz information transmitted from the office side via the demodulator 210. Using the 400-Hz signal input thereto, the phase discriminator 250 determines whether a received DMT symbol lies within the FEXT interval, the NEXT interval or outside these intervals and inputs the result to the selector 260. The latter outputs the above-mentioned ERROR signal to a NEXT-interval S/N measurement unit 270 or FEXT-interval S/N measurement unit 280 in accordance with the information that enters from the phase discriminator 250. Each S/N measurement unit integrates ERROR to calculate the S/N ratio and each outputs the S/N ratio

to a transmit-bit-count conversion unit 290 carrier by carrier. From the entered carrier-by-carrier S/N ratios, the transmit-bit-count conversion unit 290 calculates the bit count (bitmap) transmitted carrier by carrier and calculates a bitmap b-NEXT for the NEXT interval and a bitmap b-FEXT for the FEXT interval.

Frame structure

A hyperframe has been introduced for the purpose of providing a digital subscriber line transmission system that is capable of transmitting an ADSL signal satisfactorily in an environment where there is the above-described crosstalk from an ISDN ping-pong transmission. The ISDN ping-pong transmission switches between transmit/receive every half-cycle of the 400-Hz clock whose period is 2.5 ms. On the other hand, one symbol, which is the unit of transmission in ADSL transmission whose institutionalization as a global standard is proceeding, has a duration of about 0.246 ms. Accordingly, since 34 cycles of the ISDN ping-pong transmission, which is the least common multiple of the two types of communication, and the length of time of 345 DMT symbols in ADSL transmission coincide, this interval is defined as a "hyperframe".

As shown in Fig. 37, it is so arranged that one frame becomes one symbol in ADSL. At the time of normal data communication, one superframe is constructed from 68 ADSL frames for data and one synchronization frame (S). There are also cases where an inverse

synchronization symbol (I) is used instead of the synchronization symbol (S). The inverse synchronization symbol (I) is a symbol realized by rotating the phase of each carrier of the synchronization symbol (S) by 180°.

5 As shown in Fig. 37, one hyperframe is constructed by collecting together five superframes (= 345 symbols). Fig. 37 illustrates the case for the downstream direction in which the ADSL unit ATU-C on the office side transmits an ADSL signal to the ADSL unit ATU-R on
10 the subscriber side. In this case it has been decided that the inverse synchronization symbol (I) be situated in the fourth superframe of one hyperframe. In the case of the upstream direction, the inverse synchronization symbol (I) is contained in the first superframe of one
15 hyperframe. Further, one hyperframe is synchronized to 34 cycles of the 400-Hz signal in ISDN ping-pong transmission.

Alternative frame structure

In a case where an ISDN ping-pong transmission line
20 is close to an ADSL, the ADSL is affected by both NEXT and FEXT TCM crosstalk from the ISDN ping-pong transmission line, as set forth above. For the purpose of providing a digital subscriber line transmission system that is capable of transmitting an ADSL signal
25 satisfactorily in an environment where there is the above-described crosstalk from an ISDN ping-pong transmission, there is a method available which, unlike that which relies upon the above-mentioned hyperframe,

transmits ADSL symbols upon synchronizing them to an ISDN ping-pong transmission.

In accordance with ISDN ping-pong transmission, the OCU on the office side transmits the downstream data in the first-half cycles of 400 Hz and receives the upstream data in the second-half cycles of 400 Hz in sync with the ISDN 400-Hz signal TTR, as illustrated in Fig. 38. In ADSL transmission also, the ADSL unit on the office side transmits ADSL symbols for the downstream FEXT interval in the first-half cycles of 400 Hz and transmits ADSL symbols for the downstream NEXT interval in the second-half cycles of 400 Hz in sync with the ISDN 400-Hz signal TTR. This is true also with regard to the ADSL unit on the subscriber side. That is, two bitmaps are prepared, namely a bitmap (DMT symbol A) for the NEXT reception interval and a bitmap (DMT symbol B) for the FEXT reception interval. Then, as shown in Fig. 38, the number of transmitted bits is reduced to improve S/N tolerance by transmitting the DMT symbols A in the NEXT interval and the number of transmitted bits is increased to enlarge transmission capacity by transmitting the DMT symbols B in the FEXT interval. By setting the cyclic prefix length to an appropriate length at this time, the number of ADSL symbols for the FEXT interval and the number of ADSL symbols for the NEXT interval are made to coincide. For example, a cyclic prefix of 40 samples which results in 250 μ s per DMT symbol is adopted as opposed to an

original cyclic prefix of 32 samples which results in 246 μ s per DMT symbol, whereby one period of TCM crosstalk and the length of time of ten DMT signals are made to agree.

5 Introduction of TDD-xDSL

A TDD-xDSL (time-division duplex-xDSL) scheme is being considered as an xDSL scheme that does not use the above-described sliding window and hyperframes. The TDD-xDSL scheme is one which transmits symbols in sync
10 with the above-mentioned ISDN ping-pong transmission but, unlike the method described above, it does not transmit TDD-xDSL symbols in the NEXT intervals.

When a TDD-xDSL symbol sequence 460 is transmitted in sync with an ISDN ping-pong transmission on the
15 office side, a TDD-xDSL symbol sequence 480 received on the subscriber side is affected only by FEXT 440 from the ISDN, as shown in Fig. 39. When a TDD-xDSL symbol sequence 490 is transmitted in sync with an ISDN ping-pong transmission on the subscriber side, a TDD-xDSL
20 symbol sequence 470 received on the office side is affected only by FEXT 430 from the ISDN. Accordingly, it is possible for a TDD-xDSL symbol sequence to avoid being affected by NEXT from an ISDN ping-pong transmission. In accordance with this transmission
25 system, the two types of bitmaps that were required with the dual bitmap method are no longer necessary; here only one is sufficient, just as in the FEXT bitmap method.

ISI removal method

The time domain equalizer (TEQ) shown in Fig. 29 operates using the cyclic prefix in the manner described below.

5 A DMT symbol which enters the parallel-to-serial conversion buffer 40 in Fig. 29 represents a signal state that has no waveform distortion, as illustrated in (a) of Fig. 40. The parallel-to-serial conversion buffer 40 executes processing through which the 32
10 symbols at the end of this DMT symbol are added onto the beginning of the DMT symbol by copying, as illustrated in (b) of Fig. 40. The portion added on is referred to as the cyclic prefix. The DMT symbol onto which the cyclic prefix has been added is transmitted to the
15 receiving side following subsequent processing on the transmitting side, as shown in (c) of Fig. 40.

 A signal that has been received via the metallic line 70, the amplitude and delay characteristics of which are not constant with respect to frequency,
20 becomes distorted owing to the influence of inter-symbol interference (ISI), as illustrated in (d) of Fig. 40.

 However, the TEQ 90 has its constants set by training in such a manner that ISI falls within the cyclic prefix of 32 symbols (this is referred to as "TEQ
25 training"). When the TEQ 90 receives the signal indicated at (d) in Fig. 40, therefore, the TEQ 90 executes processing in such a manner that ISI will fall within the cyclic prefix of 32 symbols, as shown in (e)

of Fig. 40. Thereafter, the serial-to-parallel buffer
100 removes the cyclic prefix from the TEQ output. As a
result, it is possible to obtain a DMT symbol from which
the effects of ISI have been eliminated, as shown in (f)
5 in Fig. 40.

Influence of ISI on xDSL symbol

The influence of ISI on the xDSL symbol will be
described with reference to Fig. 41. Fig. 41 (a)
illustrates an ADSL transmit symbol sequence in a case
10 where a continuous signal is transmitted at the time of
training. It is assumed here that there is no
continuity between the shaded ADSL transmit symbol
illustrated in (a) of Fig. 41 and the ADSL transmit
signal that precedes it. Fig. 41(b) illustrates an ADSL
15 receive symbol sequence corresponding to the ADSL
transmit symbol sequence of Fig. 41 (a) before TEQ
training, and Fig. 41 (c) illustrates an ADSL receive
symbol sequence corresponding to the ADSL transmit
symbol sequence of Fig. 41 (a) after TEQ training.

20 Further, Fig. 41 (d) illustrates an ADSL transmit
symbol sequence onto which a cyclic prefix which
prevails at the time of normal data communication has
been added, and Fig. 41 (e) illustrates an ADSL receive
symbol sequence corresponding to the ADSL transmit
25 symbol sequence Fig. 41.(d)

(1) Influence after TEQ training

As set forth above, the TEQ acts to remove the
effects of ISI from a receive signal by using the cyclic

prefix. If the cyclic prefix is added onto each ADSL transmit training symbol at the time of normal data communication, as shown in Fig. 41 (d), the TEQ executes processing in such a manner that ISI falls within only
5 the cyclic prefix of 32 symbols, thereby removing the effects of ISI from the receive signal.

However, at the time of training in which a continuous signal based upon the same pattern is transmitted, a cyclic prefix is not added onto any ADSL
10 transmit training symbol, as shown in Fig. 41 (a). The reason for this is that since a continuous signal is not affected by ISI, so cyclic prefix is unnecessary for the training symbols. On the contrary, if a cyclic prefix were added on, the symbol rate would decline
15 correspondingly and it is therefore better not to add on a cyclic prefix.

However, in a case where a burst symbol sequence is sent as a transmit signal, as in the sliding-window method (FEXT bitmap method) or in the method (TDD-xDSL)
20 of transmitting symbols in sync with ISDN ping-pong transmission, continuity of the transmit signal is lost. As a result, at the time of training in which a continuous signal is transmitted, the ADSL receive symbol at the beginning of the ADSL receive symbol
25 sequence is influenced by waveform distortion corresponding to ISI, as shown in Fig. 41 (c), and training cannot be carried out using this ADSL receive symbol at this beginning of the sequence.

(2) Influence before TEQ training

Fig. 41 (b) illustrates an ADSL receive symbol sequence resulting from the ADSL transmit symbol sequence of Fig. 41 (a) before TEQ training is performed. Here also, however, the ADSL receive symbol is distorted owing to the effects of ISI for the reason set forth above. In Fig. 41 (c), the influence of waveform distortion corresponding to ISI on the leading ADSL receive symbol falls within 32 symbols owing to the TEQ. In Fig. 41 (b), on the other hand, this is an ADSL receive symbol sequence before TEQ training is performed and in general, therefore, the influence of ISI on the ADSL receive symbol does not fall within 32 symbols. It is considered that before TEQ training is performed, the influence of waveform distortion acts upon ADSL receive symbols from the second onward as well, as shown in Fig. 41 (b). Further, there are instances where the ADSL receive symbol at the end of the ADSL receive symbol sequence also is affected by ISI, though this is not illustrated in Fig. 41

Subject

Thus, at the time of training in which a continuous signal based upon the same pattern is transmitted, a cyclic prefix is not added onto each transmit symbol. As a consequence, in TDD-xDSL transmission in which a burst symbol sequence is transmitted as a training signal, the receiving side cannot respond immediately at the rising edge of the burst symbol sequence and

waveform distortion occurs at the beginning of the burst symbol sequence. Accordingly, training is carried out only by the remaining TDD-xDSL receive symbols that have not been influenced by waveform distortion. However, in
5 an instance where four DMT symbols are transmitted in one burst of training, the DMT symbols capable of being used in training are three in number. A problem that arises, therefore, is prolonged training time.

Further, if the transmit training symbol sequence
10 falls within the receive interval (NEXT interval) of an ISDN ping-pong transmission in TDD-xDSL transmission, the transmission is influenced by NEXT from the ISDN line and the TDD-xDSL transmission cannot be performed with a favorable S/N ratio.

Further, in TDD-xDSL transmission, there is no
15 established technique for setting the frequency of a pilot-tone signal used as a timing regeneration signal so as to assure continuity of sample data in contiguous transmit burst signal sequences. A problem that arises
20 is that processing cannot be executed at an accurate timing.

Further, with TDD-xDSL, there is a phase difference between the phase of a training symbol onto which a cyclic prefix for transceiver training has not been
25 added and the phase of a symbol obtained by removing a cyclic prefix from a symbol onto which this cyclic prefix was added at the time of normal data communication. As a consequence, a problem which arises

is that the phase of a timing regeneration signal (pilot-tone signal) shifts when a sequence makes a transition from a training symbol onto which a cyclic prefix has not be added to a symbol onto which a cyclic prefix has been added (a training → normal communication transition).

Furthermore, though it is necessary for the office side to synchronize a TDD-xDSL transmission to an ISDN ping-pong transmission, the same is true on the subscriber side as well. Though the office side can obtain a 400-Hz synchronization signal to which the ISDN ping-pong transmission is synchronized, the subscriber side cannot obtain this 400-Hz synchronization signal. Accordingly, it is important for the subscriber side to have the office side report the transmission phase of the TDD-xDSL accurately so that this information can be obtained. This makes it necessary to provide means for reporting the transmission phase from the office side to the subscriber side efficiently.

The present invention has been devised based upon new findings and considerations regarding the above-described points and its object is to provide a concrete method concerning the adoption of an effective transmission technique for TDD-xDSL in an environment where noise is received from ISDN ping-pong transmission or other TDD-xDSL transmissions, or a digital subscriber line transmission apparatus having means for implementing this method.

Another object of the present invention is to shorten training time.

Another object of the present invention is to so arrange it that a transmit training symbol sequence
5 after the addition thereto of redundancy data will not fall within the receive interval (NEXT interval) of an ISDN ping-pong transmission or TDD-xDSL transmission, thereby eliminating the effects of NEXT from an ISDN line so that a TDD-xDSL transmission can be performed
10 with an excellent S/N ratio.

A further object of the present invention is to assure continuity of sample data in contiguous transmit burst symbol sequences.

A further object of the present invention is to so
15 arrange it that when there is sequence transition from training to normal data communication, phase shift of a timing regeneration signal (pilot-tone signal) will not occur.

A further object of the present invention is to
20 report timing information, e.g., the phase of an ISDN 400-Hz signal from the office side to the subscriber side accurately and efficiently.

Disclosure of the Invention

In a TDD-xDSL transmission method according to the
25 present invention, a DMT symbol sequence is transmitted upon adding some data that is contained within the DMT symbol sequence onto the beginning or end or onto both the beginning and end of the sequence redundantly at the

time of training, which is carried out before normal communication, and the redundancy data is then removed on the receiving side. If this expedient is adopted, distortion develops in the redundancy portions but not
5 in the portions of the training symbols. Training can be carried out using all training symbols and training time can be shortened.

Further, the length of the transmit training symbol sequence after the redundancy data is added on is made
10 such that the training symbol sequence will fall within the transmit interval of an ISDN ping-pong transmission. For example, the system is set up in such a manner that the training symbol sequence will not fall within the receive interval (NEXT interval) of an ISDN ping-pong
15 transmission. If this arrangement is adopted, communication with an excellent S/N ratio can be performed by eliminating the effects of NEXT from ISDN ping-pong transmission.

Further, in a TDD-xDSL transmission, the frequency
20 of a pilot-tone signal serving as a timing regeneration signal is set so as to assure continuity of sample data in contiguous transmit burst symbol sequences. If this arrangement is adopted, the phase of a pilot-tone signal will not shift between contiguous transmit burst symbol
25 sequences and processing can be executed at an accurate timing.

In TDD-xDSL transmission according to the present invention, the phase difference between the phase of a

training symbol onto which a cyclic prefix has not been added and the phase of a DMT symbol obtained by removing the cyclic prefix at the time of normal data communication is made a whole-number multiple of the
5 cycle of the pilot-tone signal used as a timing regeneration signal. As a result, when there is a sequence transition from training to normal data communication, the timing regeneration signal (pilot-tone signal) does not develop a phase shift. This makes
10 accurate processing possible.

In TDD-xDSL transmission according to the present invention, when the subscriber side is notified of transmit timing (the phase of an ISDN 400-Hz signal) of a TDD-xDSL burst signal on the office side, a tone-
15 signal the phase whereof varies one or more times within one transmission burst is transmitted separately of the pilot-tone signal, and this change in the phase of the tone-signal is detected on the receiving side to identify the transmit timing of the TDD-xDSL burst
20 signal. If this expedient is adopted, a correct TDD-xDSL transmission can be performed by detecting the transmit timing (the phase of an ISDN 400-Hz signal) at the time of training of a TDD-xDSL transmission. In this case the phase of the tone-signal can be changed
25 90° or 180°. If this arrangement is adopted, the transmit timing (the phase of an ISDN 400-Hz signal) can be recognized reliably even if the transmit timing is unknown initially.

Brief Description of the Drawings

Fig. 1 is a diagram useful in describing a transmit symbol sequence at the time of TDD-xDSL training;

Fig. 2 is a diagram illustrating the structure of a transmit frame based upon the TDD-xDSL method (at the
5 time of training);

Fig. 3 is a diagram illustrating the structure of a transmit frame based upon the TDD-xDSL method (at the time of normal communication);

10 Fig. 4 is a diagram useful in describing frame phase relationship between bursts (in the downstream case);

Fig. 5 is another diagram useful in describing frame phase relationship between bursts (in the
15 downstream case);

Fig. 6 is a diagram showing the phase relationship between burst frames at the time of training and at the time of normal communication;

Fig. 7 is diagram useful in describing a method of
20 reporting transmit phase (the phase of an ISDN 400-Hz signal) of a TDD-xDSL at the time of training;

Fig. 8 is diagram useful in describing phase-change conveyance patterns;

Fig. 9 is a block diagram illustrating a subscriber
25 transmission system based upon DMT modulation in accordance with the present invention;

Fig. 10 is a block diagram of an arrangement for reconstructing a symbol sequence in accordance with the

present invention;

Fig. 11 is a time chart indicating an output sequence operation (at the time of training);

Fig. 12 is a time chart indicating an output
5 sequence operation (at the time of normal communication);

Fig. 13 is a block diagram of a sequencer on the transmitting side;

Fig. 14 is a block diagram of various components on
10 the receiving side;

Fig. 15 is a time chart indicating a receive sequence operation (at the time of training);

Fig. 16 is a time chart indicating a receive sequence operation (at the time of normal
15 communication);

Fig. 17 is a diagram showing the phase relationship between burst frames at the time of training and at the time of normal communication according to a first embodiment of the present invention;

Fig. 18 is a diagram illustrating the structure of
20 a burst frame (at the time of normal communication) according to the first embodiment;

Fig. 19 is a diagram illustrating the structure of a burst frame (at the time of training) according to the
25 first embodiment;

Fig. 20 is a diagram useful in describing a first worst condition (at the time of training) according to the first embodiment;

Fig. 21 is a diagram useful in describing a second worst condition (at the time of training) according to the first embodiment;

Fig. 22 is a diagram useful in describing a third worst condition (at the time of training) according to the first embodiment;

Fig. 23 is diagram useful in describing two worst conditions;

Fig. 24 is a diagram useful in describing the phase difference between a transmit symbol sequence for training and a transmit symbol sequence at the time of normal communication;

Fig. 25 is a diagram useful in describing the phase relationship between burst frames at the time of training and at the time of normal communication according to a second embodiment of the present invention;

Fig. 26 is a diagram illustrating the structure of a burst frame (at the time of normal communication) according to the second embodiment;

Fig. 27 is a diagram illustrating the structure of a burst frame (at the time of training) according to the second embodiment;

Fig. 28 is a diagram useful in describing a DMT transmission spectrum;

Fig. 29 is a functional diagram of a subscriber transmission system which relies upon DMT modulation;

Fig. 30 is a diagram useful in describing the band

of ISDN ping-pong transmission and the band of ADSL transmission;

Fig. 31 is a diagram useful in describing crosstalk noise;

5 Fig. 32 is diagram useful in describing interference (crosstalk) from an ISDN line on an ADSL;

Fig. 33 is a diagram useful in describing a sliding window;

10 Fig. 34 is a diagram useful in describing a dual bitmap and a FEXT bitmap;

Fig. 35 is a diagram useful in describing the creation of a bitmap based upon a B & G protocol;

Fig. 36 is a block diagram useful in describing measurement of S/N ratio in every NEXT/FEXT interval;

15 Fig. 37 is a diagram useful in describing a hyperframe scheme;

Fig. 38 is a diagram useful in describing a transmission method in which ADSLs symbol are synchronized to an ISDN ping-pong transmission;

20 Fig. 39 is a diagram useful in describing a method of transmitting TDD-xDSL symbols;

Fig. 40 is diagram useful in describing a method of removing ISI; and

25 Fig. 41 is diagram useful in describing the effects of ISI on xDSL symbols.

Best Mode for Carrying Out the Invention

(A) Overview of the present invention;

The present invention has a number of

characterizing features, which are set forth below, when applied in TDD-xDSL transmission in an environment in which the TDD-xDSL transmission is influenced by periodic noise from an ISDN ping-pong transmission line.

5 (a) First characterizing feature

A first characterizing feature is the transmission of a training symbol sequence 500 of the kind shown in Fig. 1 in the training of an ADSL unit (transceiver) of a TDD-xDSL. A conventional transmit symbol sequence 502
10 is constructed by connecting training symbols 501 each of which is devoid of a cyclic prefix. In the training of a TDD-xDSL transceiver, (1) a pattern 503, which is identical with the end portion of the leading training symbol 501, is added onto the beginning of the
15 conventional transmit symbol sequence 502 as a redundancy signal and is composed of a predetermined number of samples, thereby making it possible to form a pattern of continuous training symbols that includes the portion added on. The length of the portion added on is
20 a predetermined sample count n_1 that is larger than a cyclic prefix. (2) Or, in another option, a pattern 504 identical with the leading-end portion of the final training symbol 501 is added onto the end of the transmit symbol sequence 502 as a redundancy signal and
25 is composed of a sample count n_2 determined separately of the sample count n_1 attached to the beginning in option (1) above. (3) Or, in yet another option, the redundancy signals 503, 504 are added on to both the

beginning and end, respectively, of the transmit symbol sequence 502.

With the DMT method, symbols are so arranged that an integral number of periods of each carrier will fall within one symbol. When symbols having the same pattern are connected, therefore, a continuous signal can be sent. Accordingly, by adding the pattern 503, which is identical with the end portion of the training symbol, onto the beginning of the transmit symbol sequence, or by adding the pattern 504, which is identical with the leading-end portion of the training symbol onto the end of the sent symbol sequence, or by doing both, the length of the connected signal can be increased.

If a redundancy signal is thus added onto the beginning or end of a transmit symbol sequence, the redundancy signal portions are affected by distortion caused by ISI but the transmit symbol sequence develops no distortion. All of these symbols, therefore, can be used as training symbols. This makes it possible to shorten training time. It should be noted that transmission time is not prolonged even though the redundancy signals are added on. The reason is that the redundancy signals can be transmitted utilizing those periods in the transmit intervals of the TDD-xDSL in which signals are not transmitted.

(b) Second characterizing feature

A second characterizing feature is that the transmit timing and length of the training symbol

sequence are set in such a manner that the training symbol sequence after the redundancy sample sequence has been added on according to the first characterizing feature will not fall within the receive interval (NEXT) of an ISDN ping-pong transmission.

More specifically, the transmit timing of a TDD-xDSL transmission and the length of a transmit training symbol sequence are set in such a manner that the transmit training symbol sequence of a TDD-xDSL will fall within the transmit frame interval of an ISDN ping-pong transmission or within an interval obtained by combining the transmit frame interval of an ISDN ping-pong transmission and a guard-time interval between transmission and reception in an ISDN ping-pong transmission.

Reference will be had to Fig. 2 to describe the requirements for fitting the TDD-xDSL transmit training symbol sequence 500 into a transmit interval 601 of an ISDN ping-pong transmission. Let $D (= 3.125 \mu s \times 377 = 1.178125 \text{ ms})$ represent the length of time of an ISDN ping-pong transmission interval; $a (= 18.75 \sim 23.4375 \mu s)$ the length of the the transmit/receive guard time of the ISDN ping-pong transmission; S_1 the length of the transmission time of the training symbol sequence 502 before TDD-xDSL redundancy data is added on; x_1 and y_1 the lengths of the transmission times of the redundancy signals 503, 504 added onto the beginning and end, respectively, of the DMT symbol sequence for training;

and α_1 , β_1 the margins between the interval of the transmit training symbol sequence 500 and the transmit interval 601 of the ISDN ping-pong transmission. A relation that is to be satisfied by the present

5 invention is as follows:

$$S_1 + \alpha_1 + \beta_1 + x_1 + y_1 \leq D + a \quad (1)$$

(where $0 \leq \alpha_1$, $0 \leq \beta_1$)

or

$$S_1 + \alpha_1 + \beta_1 + x_1 + y_1 \leq D \quad (2)$$

10 (where $0 \leq \alpha_1$, $0 \leq \beta_1$)

Further, let m represent the number of samples within a DMT symbol that is devoid of a cyclic prefix; N the number of DMT symbols devoid of a cyclic prefix included in the training symbol sequence 500; and f_d the frequency spacing of the DMT carriers. Accordingly, S_1 , x_1 and y_1 can be expressed by the following equations:

$$S_1 = N \times m \times [1/(m \times f_d)] = N/f_d \quad (3a)$$

$$x_1 = n_x \times [1/(m \times f_d)] \quad (3b)$$

$$y_1 = n_y \times [1/(m \times f_d)] \quad (3c)$$

20 where $m = 2n$ (n is a natural number) and n_x , n_y are arbitrary positive integers which signify the sample counts of x_1 , y_1 and $(n_x + n_y) > (m/8)$ holds.

Similarly, at the time of normal communication, as depicted in Fig. 3, it possible to obtain relations for fitting a TDD-xDSL DMT transmit symbol sequence 700 into the transmit interval 601 of the ISDN ping-pong transmission in a manner similar to that at the time of training. Specifically, in a manner similar to that at

the time of training, let D represent the length of time of the ISDN ping-pong transmission interval; a the length of the transmit/receive guard time of the ISDN ping-pong transmission; S_2 the length of the TDD-xDSL DMT transmit symbol sequence 700; α_2 , β_2 the margins between the interval of the TDD-xDSL DMT transmit symbol sequence 700 and the transmit interval 601 of the ISDN ping-pong transmission; m the number of carriers of the DMT transmit symbols; N the number of symbols contained in the symbol sequence at the time of normal communication; and f_d the frequency spacing of the DMT carriers. A relation that is to be satisfied by the present invention is as follows:

$$S_2 + \alpha_2 + \beta_2 \leq D + a \quad (4)$$

or

$$S_2 + \alpha_2 + \beta_2 \leq D \quad (4)'$$

$$S_2 = N \times (m + n_c) \times [1/(m \times f_d)] \quad (5)$$

where $0 \leq \alpha_1$, $0 \leq \beta_1$ hold and n_c is the number of samples of a cyclic prefix at the time of normal communication.

In accordance with Equations (4) - (5), a cyclic prefix length fixed at 16 samples conventionally in accordance with G.992.2 (G.lite) also can be varied over a range that satisfies Equation (4).

If the arrangement described above is adopted, the transmit timing of the TDD-xDSL training symbol sequence will fall within the transmit interval (FEXT interval) of the ISDN ping-pong transmission and leakage of NEXT noise from the ISDN line can be avoided when TDD-xDSL

training symbols are received. Further, at the time of normal communication, the transmit timing of the TDD-xDSL transmit symbol sequence will fall within the transmit interval (FEXT interval) of the ISDN ping-pong transmission and leakage of NEXT noise from the ISDN line can be avoided when TDD-xDSL transmit symbols are received.

(c) Third characterizing feature

A third characterizing feature resides in selecting the frequency of a timing regeneration signal (pilot-tone signal) in such a manner that the continuity of DMT symbols is maintained between transmit burst intervals in a TDD-xDSL.

Fig. 4 is a diagram useful in describing frame phase between transmit bursts at the time of training of a TDD-xDSL. In DMT modulation, it is desired that each symbol be a continuous DMT sample sequence. In other words, in an interval T_a in Fig. 4 in which signal transmission between transmit bursts is not carried out, it is required that the length of this interval be a whole-number multiple of the pilot-tone cycle.

Accordingly, the cycle of the pilot tone is selected in such a manner that (1) the length of the transmit symbol sequence indicated by T_b in Fig. 4 will be a whole-number multiple of the pilot-tone cycle and (2) a burst interval T_c in Fig. 4 will be a whole-number multiple of the pilot-tone cycle. If this arrangement is adopted, the length of the interval T_a can be made a

whole-number multiple of the pilot-tone cycle so that the continuity of DMT samples in contiguous transmit bursts can be maintained.

Fig. 5 is a diagram useful in describing the phase relationship of transmit symbols between bursts at the time of training and at the time of normal communication. Fig. 5 relates to frames in the downstream direction. As set forth above (in the description of the second characterizing feature), it is required that the transmit symbols 500, 700 at the time of training and at the time of normal communication fall within the transmit interval 601 of the TCM-ISDN. To achieve this, symbol transmission is carried out using the transmit interval 601 of the TCM-ISDN as the reference timing, and the burst intervals T_c , T_d at the time of training and at the time of normal communication are decided from the burst interval of the ISDN ping-pong transmission. According to the present invention, the burst intervals T_c , T_d are selected to be whole-number multiples of the cycle of a pilot-tone signal PLT, which is for setting the timing a TDD-xDSL.

(d) Fourth characterizing feature

A fourth characterizing feature resides in adopting an arrangement in which a phase difference θ_d (see Fig. 6) between the phase of the symbol 501 contained in the transmit symbol sequence 500 at the time of training using training symbols devoid of a cyclic prefix (CP) and the phase of a symbol 701 contained in the transmit

symbol sequence 700 at the time of normal communication using DMT symbols having a cyclic prefix (CP) will be a whole-number multiple of a pilot-tone cycle selected earlier.

5 Fig. 6 is a diagram useful in describing the phase relationship between transmit burst frames at the time of training and at the time of normal communication. Fig. 6 relates to the phase difference θ_d between the starting points of the symbols 501, 701 situated at the
10 beginning of the transmit symbol sequence 500 for training and the transmit symbol sequence 700 for normal communication, respectively.

 The transmit symbol sequence 500 for training and the transmit symbol sequence 700 for normal
15 communication are transmitted independently of each other in sync with the burst cycle of the ISDN ping-pong transmission. Further, the manners in which the symbols devoid of cyclic prefixes are arrayed in the respective transmit symbol sequences also differ from each other.
20 For this reason, the phases of the individual symbols 501, 701 contained in the transmit symbol sequences at the time of training and at the time of normal communication differ. It is so arranged that this phase difference θ_d will be a whole-number multiple of the
25 cycle of the pilot-tone signal PLT.

 Methods of arranging it so that the phase difference will become a whole-number multiple of the cycle of the pilot-tone signal PLT include a method of

adjusting the cycle of the pilot-tone signal PLT and a method of shifting the transmit timing of the transmit symbol sequence 700 for normal communication relative to the transmit symbol sequence 500 for training.

5 (e) Fifth characterizing feature

A fifth characterizing feature resides in transmitting a tone signal separately of the pilot-tone signal PLT which is for timing regeneration, at the time of training, whereby the office side notifies the
10 subscriber side of the phase of the ISDN 400-Hz signal (i.e., reports the transmission phase of the TDD-xDSL on the office side).

The tone signal added on in addition to the pilot-tone signal PLT always includes one or more phase-change
15 points within one burst. The xDSL unit on the subscriber side, therefore, finds the phase-change point and adopts a time which is a set time before or a set time after the phase-change point as the TDD-xDSL transmit timing of the xDSL unit on the office side or
20 as the rising edge of the 400-Hz signal. By virtue of the fifth characterizing feature, timing can be regenerated more easily and in a shorter period of time than with the conventional method.

Figs. 7 (a) and 7 (b) are diagrams useful in
25 describing regeneration of the timing of the ISDN 400-Hz signal by a tone added on anew. In a case where the transmit symbol sequence of one burst contains four training symbols, Fig. 7 (a) shows an example in which

phase changes one time within one burst and Fig. 7 (b) an example in which phase changes twice within one burst.

In Fig. 7 (a), the phase of training symbols
5 changes from pattern A to pattern B between second and third symbols. In Fig. 7 (b), the phase of training symbols changes from pattern B to pattern A between first and second symbols and from pattern A to pattern B between third and fourth symbols. It is also
10 permissible to adopt an arrangement in which there is a shift from pattern A to a new pattern C between the third and fourth symbols.

In the example of Fig. 7 (a), a time which is a set time period T_1 prior to phase-change detection time is
15 the timing of the rising edge of the ISDN 400-Hz signal TTR. In the example of Fig. 7 (b), a time which is a set time period T_2 prior to the average time of two phase-change detection times T_{21} , T_{22} is the timing of the rising edge of the ISDN 400-Hz signal TTR.

20 (f) Sixth characterizing feature

A sixth characterizing feature resides in selecting patterns A, B in the above-mentioned tone that is separate from the pilot-tone signal PLT in such a manner that the phase difference between them will be 90 or
25 180° in a QAM constellation diagram, and effecting a change $A \rightarrow B$ or $B \rightarrow A$ within one burst to thereby convey the phase change.

Figs. 8 (a), 8 (b) are diagrams useful in

describing patterns A and B and illustrate a method of selecting the patterns A, B in a case where the simplest 4QAM is used as the DMT symbol. Fig. 8 (a) illustrates an example of a constellation when the phase difference between the patterns A and B is 90° , and Fig. 8 (b) illustrates an example of a constellation when the phase difference between the patterns A and B is 180° .

(B) Embodiments

(a) Overall construction

Fig. 9 is a block diagram of a subscriber transmission system using the TDD-xDSL method according to the present invention. Components in Fig. 9 identical with those shown in Fig. 29 are designated by like reference characters. This system differs from that of Fig. 29 in that the transmitting side is provided with a sequencer 310, selector 320 and training-signal generating circuit 330 and the receiving side is provided with a signal detecting circuit 340, sequencer 350, pilot-phase detecting circuit 360 and training signal processor 370.

The sequencer 310 on the transmitting side (1) generates a training-state signal TRN and a communication-state signal DMN upon distinguishing between training time and normal communication time, and (2) controls the parallel-to-serial conversion buffer 40 and outputs the transmit symbol sequence 500 for training (see Fig. 1) and the transmit symbol sequence 700 for normal communication (see Fig. 3).

The training-signal generating circuit 330 (1) outputs various training signals at the time of training and (2) generates the timing-regeneration pilot-tone signal PLT in the transmit interval of the TDD-xDSL.

5 The pilot-tone signal PLT is transmitted to the receiving side by carrier #64. The training-signal generating circuit 330 transmits another tone-signal separately of the pilot-tone signal PLT by carrier #48 at training time to report the phase of the ISDN 400-Hz
10 signal (the transmit phase of the TDD-xDSL on the office side) from the office side to the subscriber side (see Figs. 7, 8).

In the transmit interval of the TDD-xDSL, the selector 320 (1) selects the training signal output from
15 the training-signal generating circuit 330 and inputs this signal to the IFFT circuit 30 at training time, and (2) selects the transmit data output from the encoder 20 to the IFFT circuit 30 at the time of normal communication.

20 The signal detecting circuit 340 monitors the level of the output signal from the A/D converter 80 to detect when the training signal has been sent from the transmitting side, and the sequencer 350 controls the serial-to-parallel conversion buffer 100 to exercise
25 control in such a manner that the one symbol of data from which the redundancy signal / cyclic prefix has been removed at training time / normal communication time, respectively, is input to the FFT circuit 110. On

the basis of the signal output from the #64 output terminal of the FFT circuit, the pilot-phase detecting circuit 360 detects the phase of the pilot-tone signal PLT and controls the A/D conversion timing of the A/D converter 80.

The training signal processor 370 analyzes the training signal to detect the ISDN 400-Hz signal and detects the start of normal communication based upon sequence switching data sent from the transmitting side.

- 10 (b) Arrangement for generating transmit symbol sequence at training time and normal communication time

Fig. 10 is a block diagram of an arrangement for generating a symbol sequence at training time and normal communication time. Components in Fig. 10 identical with those shown in Fig. 9 are designated by like reference characters. Fig. 11 is a time chart for describing an output sequence operation at training time. This is for a case where a redundancy signal 503 having a length of 128 samples is added onto the beginning of the sequence and a redundancy signal 504 having a length of 8 samples is added onto the end of the sequence. Fig. 12 is a time chart for describing an output sequence operation at the time of normal communication. This is for a case where the cyclic prefix has a length of 16 samples.

(b-1) Creation of training symbol sequence

The sequencer 310 generates various control signals

in such a manner that the transmit symbol sequence 500 for training will fall within the transmit interval of the ISDN ping-pong transmission. More specifically, at start-up, the sequencer 310 controls switching between
5 training time and normal transmission time by timer control, inputs a training / normal communication switching signal DTSL to the selector 320 and inputs the training-state signal TRN to the training-signal generating circuit 330. In response to the training /
10 normal communication switching signal DTSL, the selector 320 selects a training signal, which is output from the training-signal generating circuit 330, and inputs this signal to the IFFT circuit 30 at the time of training, and selects the transmit data output from the encoder 20
15 and inputs this data to the IFFT circuit 30 at the time of normal communication. The training-signal generating circuit 330 generates a predetermined training signal at training time.

At training time, the sequencer 310 generates (1) a
20 P/S load timing signal PSLD, (2) a P/S output mask signal PSMK and (3) a P/S output select signal PSSL (= "11") upon elapse of a predetermined time t_1 from the rising edge of the ISDN 400-Hz signal TTR, as shown in Fig. 11.

25 The P/S load timing signal PSLD is a signal which loads the result of the IFFT operation (256 items of signal-point data) into a buffering unit 40a in the parallel-to-serial conversion buffer 40. The P/S output

mask signal PSMK allows a data output from the buffering unit 40a when at the high level and inhibits a data output from the buffering unit 40a when at the low level. The P/S output select signal PSSL designates successive read-out of signals starting from the 0th signal, the 128th signal or the 240th signal among the 256 signals that have been stored in the buffering unit 40a. More specifically, the P/S output select signal PSSL takes on the values "10", "11", "01" and the selector 40b reads out signals in numerical order starting from (1) the 0th signal of buffering unit 40a if the signal PSSL is "10", (2) the 128th signal of buffering unit 40a if the signal PSSL is "11" and (3) the 240th signal of buffering unit 40a if the signal PSSL is "01".

15 If the P/S load timing signal PSLD is generated, 256 signals output from the IFFT circuit 30 are stored in the buffering unit 40a of the parallel-to-serial conversion buffer 40. Next, in response to the P/S output select signal PSSL of logic "11", the selector 40b reads signals out of the buffering unit 40a in numerical order starting from the 128th signal in sync with a P/S operating clock PSCL and outputs these signals via a mask circuit 40c. As a result, 128 signals from the 128th to the 255th are read out as the redundancy signal 503 and then 256 training signals (1st symbol data) from the 0th to the 255th are read out.

 If read-out of the initial training symbol is completed, the sequencer 310 generates the P/S load

timing signal PSLD again and generates the P/S output
select signal PSSL of logic "10". As a result, the next
256 signals output from the IFFT circuit 30 are stored
in the buffering unit 40a of the parallel-to-serial
5 conversion buffer 40. Next, in response to the P/S
output select signal PSSL of logic "10", the selector
40b reads signals out of the buffering unit 40a in
numerical order starting from the 0th signal in sync with
a P/S operating clock PSCL and outputs these signals via
10 a mask circuit 40c. As a result, 256 training signals
(2nd symbol data) from the 0th to the 255th are read out.

If read-out of the 2nd training symbol is completed,
the sequencer 310 generates the P/S load timing signal
PSLD and the next 256 signals output from the IFFT
15 circuit 30 are stored in the buffering unit 40a of the
parallel-to-serial conversion buffer 40. The selector
40b reads signals out of the buffering unit 40a in
numerical order starting from the 0th signal in sync with
the P/S operating clock PSCL and outputs these signals.
20 As a result, 256 training signals (3rd symbol data) from
the 0th to the 255th are read out.

If read-out of the 3rd training symbol is completed,
the sequencer 310 generates the P/S load timing signal
PSLD and the next 256 signals output from the IFFT
25 circuit 30 are stored in the buffering unit 40a of the
parallel-to-serial conversion buffer 40. The selector
40b reads signals out of the buffering unit 40a in
numerical order starting from the 0th signal in sync with

the P/S operating clock PSCL and outputs these signals.
As a result, 256 training signals (the final symbol
data) from the 0th to the 255th are read out. Thereafter,
eight signals from the 0th to the 7th are read out and
5 output as the redundancy signal 504.

If output of the redundancy signal 504 is
completed, the sequencer 310 places the P/S output mask
signal PSMK at the low level and places the P/S output
select signal at logic "00" to establish the non-
10 selected state.

Thereafter, at training time, the above-described
operation is repeated whenever the ISDN 400-Hz signal
TTR rises to create and transmit the transmit symbol
sequence for training.

15 (b-2) Creation of transmit symbol sequence
at time of normal communication

The sequencer 310 generates various control signals
in such a manner that the transmit symbol sequence 700
for normal communication will be transmitted within the
20 transmit interval of the ISDN ping-pong transmission.
More specifically, at start-up, the sequencer 310
exercises control to switch from the training state to
the normal communication state at elapse of a
predetermined period time following start-up. As a
25 result, the selector 320 selects and inputs the transmit
data from the encoder 20 to the IFFT circuit 30 selects
the pilot-tone signal PLT from the training-signal
generating circuit 330 and inputs this signal to the #64

terminal of the IFFT circuit 30.

Further, at the time of normal communication, the sequencer 310 generates (1) the P/S load timing signal PSLD, (2) the P/S output mask signal PSMK and (3) the
5 P/S output select signal PSSL (= "01") upon elapse of a predetermined time t_2 from the rising edge of the ISDN 400-Hz signal TTR.

If the P/S load timing signal PSLD is generated, 256 signals output from the IFFT circuit 30 are stored
10 in the buffering unit 40a of the parallel-to-serial conversion buffer 40. Next, in response to the P/S output select signal PSSL of logic "01", the selector 40b reads signals out of the buffering unit 40a in numerical order starting from the 240th signal in sync
15 with a P/S operating clock PSCL and outputs these signals via a mask circuit 40c. As a result, 16 signals from the 240^h to the 255th are read out as the cyclic prefix and then 256 transmit signals (1st symbol data) from the 0th to the 255th are read out.

20 If read-out of the initial transmit symbol is completed, the sequencer 310 generates the P/S load timing signal PSLD again. As a result, the next 256 signals output from the IFFT circuit 30 are stored in the buffering unit 40a of the parallel-to-serial
25 conversion buffer 40. Next, in response to the P/S output select signal PSSL of logic "01", the selector 40b reads 16 signals from the 240th to the 255th out of the buffering unit 40a as the cyclic prefix in sync with

the P/S operating clock PSCL and then reads out 256 transmit signals (2nd symbol data) from the 0th to the 255th and outputs these signals. If 3rd and 4th symbol data with attached cyclic prefixes are subsequently read out and output in similar fashion, the sequencer 310 places the P/S output mask signal PSMK at the low level and places the P/S output select signal PSSL at logic "00" to establish the non-selected state.

Thereafter, at normal communication time, the above-described operation is repeated by the sequencer whenever the ISDN 400-Hz signal TTR rises to create and transmit the transmit symbol sequence for normal communication.

(b-3) Construction of the sequencer

Fig. 13 is a block diagram of a sequencer in the ADSL unit on the office side. A sequence switching unit 311 generates the training-state signal TRN and a normal-communication-state signal CMN by timer control at start-up, and a signal generator 312 for generating the ISDN 400-Hz signal outputs the 400-Hz signal TTR of the ISDN ping-pong transmission. Further, a P/S operating clock generator 313 generates the P/S operating clock PSCL in sync with the ISDN 400-Hz signal TTR, and a pilot-tone signal generator 314 applies 1/4 frequency division to the P/S operating clock PSCL and outputs the pilot-tone signal PLT for timing regeneration. Though this illustrates an example in which the ISDN 400-Hz signal TTR is output from the

signal generator 312, this signal may be input externally.

The reason for outputting the pilot-tone signal PLT by 1/4 frequency division of the P/S operating clock PSCL is as follows: If carrier frequency spacing is 4 kHz, the number of samples within one DMT symbol is 256 and #64 is used as the pilot-tone transmission carrier, the FFT sampling frequency on the receiving side will be 1024 kHz ($= 4 \times 256$ kHz) based upon the carrier frequency spacing and number of carriers. Further, the frequency of the pilot tone will be $4 \text{ kHz} \times 64 = 256$ kHz. In other words, the data per cycle of the pilot tone is four sample's worth. On the other hand, the P/S operating clock PSCL is transmitted serially from the parallel-to-serial conversion buffer 40 at 1024 kHz. This is equal to the FFT sampling frequency. Accordingly, the pilot-tone signal PLT can be generated by subjecting the P/S operating clock PSCL to 1/4 frequency division.

At training time, a first timing generator 315 for generating a first transmit symbol output timing generates a symbol output timing signal TSOT in sync with the pilot-tone signal PLT upon elapse of the predetermined time t_1 from the rising edge of the ISDN 400-Hz signal TTR.

At normal communication time, a second timing generator 316 for generating a transmit symbol output timing generates a transmit symbol output timing signal

DSOT in sync with the pilot-tone signal PLT upon elapse of the predetermined time t_2 from the rising edge of the ISDN 400-Hz signal TTR.

On the basis of the training-state signal TRN,
5 normal-communication-state signal CMN and transmit
symbol output timing signals TSOT, DSOT, a signal
generator 317 generates various control signals (the P/S
load timing signal PS LD, P/S output select signal PSS L,
P/S output mask signal PSMK, training / normal
10 communication switching signal DTSL, etc.) in sync with
the P/S operating clock PSCL and outputs these signals.

By virtue of the fact that the timing generators
315, 316 generate the transmit symbol output timing
signals TSOT, DSOT in sync with the pilot-tone signal
15 PLT, the phase difference θ_d (see Fig. 6) between the
individual symbols 501, 701 contained in the transmit
symbol sequence can be adjusted to a whole-number
multiple of the cycle of the pilot tone at training time
and at normal communication time.

20 Further, by virtue of the fact that the timing
generators 315, 316 generate the transmit symbol output
timing signals TSOT, DSOT in sync with the pilot-tone
signal PLT, (1) the length of the transmit symbol
sequence can be made a whole-number multiple of the
25 cycle of the pilot tone and (2) the transmit burst
interval can be made a whole-number multiple of the
cycle of the pilot tone at training time and normal
communication time, respectively. As a result, in TDD-

xDSL transmission, an interval in which no signal is transmitted can be made a whole-number multiple of the pilot-tone cycle in the interval between temporally contiguous transmit bursts, and the continuity of DMT samples in contiguous transmit bursts can be maintained. Since the number of samples in the transmit symbol sequence at training time is 1160 ($= 128 + 256 \times 4 + 8$), this is 290 times the pilot-tone cycle, and since the number of samples in the transmit symbol sequence at normal communication time is 1088 [$= (16 + 256) \times 4$], this is 272 times the pilot-tone cycle. Equation (1), therefore, is satisfied.

(c) Components on receiving side

Fig. 14 is a block diagram of the principal components on the receiving side. Components in Fig. 14 identical with those shown in Fig. 9 are designated by like reference characters. The signal detecting circuit 340 monitors the level of the output signal from the A/D converter 80, which subjects the input signal to an analog-to-digital conversion at the FFT sampling frequency, to thereby detect when the training signal has been sent from the transmitting side, and inputs a training-starting signal TRST to the sequencer 350. The training signal processor 370 analyzes the training signal and detects the timing of the ISDN 400-Hz signal TTR. In addition, the training signal processor 370, on the basis of sequence switching data sent from the transmitting side, detects the start timing of normal

communication and inputs a normal-communication start
signal CMST to the sequencer 350. The latter has an S/P
operating clock generator 350a and a control signal
generator 350b. The S/P operating clock generator 350a
5 generates a S/P operating clock SPCL, the frequency of
which is the same as the FFT sampling frequency, in sync
with the ISDN 400-Hz signal TTR. At training time, the
control signal generator 350b generates various timing
signals shown in Fig. 15 in sync with the S/P operating
10 clock SPCL. At normal communication time following
detection of the timing of the ISDN 400-Hz signal TTR
and completion of phase control of the pilot-tone
signal, the control signal generator 350b generates
various timing signals shown in Fig. 16 in sync with the
15 S/P operating clock SPCL.

(c-1) Receive sequence operation at training time
(see Fig. 15)

If the signal detecting circuit 340 generates the
training-starting signal TRST, the sequencer 350
20 generates an S/P load timing signal SPLD after the 128-
sample redundancy signal arrives. As a result, the
redundancy signal 503 that was added onto the beginning
of the transmit symbol sequence 500 can be removed. If
the S/P load timing signal SPLD is generated, the
25 serial-to-parallel conversion buffer 100 (Fig. 9)
successively stores the sample data output by the TEQ 90
in sync with the S/P operating clock SPCL. After one
symbol (= 256 samples) is preserved, the sequencer 350

generates an FFT load timing signal FFTLD to load the one symbol's worth of sample data from the serial-to-parallel buffer 100 to the FFT circuit 110. The latter performs an FFT operation at a predetermined timing and
5 outputs the results of the operation.

Meanwhile, the serial-to-parallel conversion buffer 100 continues to successively store the sample data output from the TEQ 90 even after the FFT load timing signal FFTLD is generated and inputs the one symbol's
10 worth (= 256 samples) of data to the FFT circuit 110 by the FFT load timing signal FFTLD generated from the sequencer 350 after the one symbol's worth of data is preserved.

The same receive sequence operation is thenceforth
15 repeated. After the final symbol is input to the FFT circuit 110, the sequencer 350 places the S/P load timing signal SPLD at the low level and removes the redundancy signal 504 that was added onto the end of the transmit symbol sequence.

20 (c-2) Receive sequence operation at normal communication time (see Fig. 16)

If the normal-communication start signal CMST enters from the training signal processor 370, the sequencer 350 immediately generates the S/P load timing
25 signal SPLD. If the S/P load timing signal SPLD is generated, the serial-to-parallel buffer 100 (Fig. 9) successively stores the sample data output by the TEQ 90 in sync with the S/P operating clock SPCL. The

sequencer 350 generates the FFT load timing signal FFTLD at the timing at which the 272 ($= 16 + 256$) items of sample data corresponding to the cyclic prefix (CP) and one symbol were stored in the serial-to-parallel conversion buffer 100. As a result, one symbol's worth of sample data minus the 16-sample cyclic prefix is loaded in the FFT circuit 110 from the serial-to-parallel buffer 100. The FFT circuit 110 performs an FFT operation at a predetermined timing and outputs the results of the operation.

Meanwhile, the serial-to-parallel conversion buffer 100 continues to successively store the sample data output from the TEQ 90 even after the FFT load timing signal FFTLD is generated and the sequencer 350 generates the FFT load timing signal FFTLD at the timing at which the 272 ($= 16 + 256$) items of new sample data were stored in the serial-to-parallel conversion buffer 100. As a result, the serial-to-parallel buffer 100 loads one symbol's worth of sample data minus the 16-sample cyclic prefix in the FFT circuit 110. The FFT circuit 110 performs an FFT operation at a predetermined timing and outputs the results of the operation.

The same processing is thenceforth repeated. After the final symbol is input to the FFT circuit 110, the sequencer 350 places the S/P load timing signal SPLD at the low level.

(d) Control of transmission of pilot-tone signal
PLT

A pilot generator 330a (Fig. 10) in the training-signal generating circuit 330 generates the pilot-tone signal in the transmit interval of the TDD-xDSL transmission. The sequencer 310 generates the select
5 signal DTSL so as to input the pilot-tone signal to the #64 terminal of the IFFT circuit 30. The IFFT circuit 30 applies IFFT processing to the pilot-tone signal and then transmits the processed signal to the receiving side via the parallel-to-serial conversion buffer 40 and
10 D/A converter 50.

On the basis of the signal output from the #64 carrier terminal of the FFT circuit 110, the pilot-phase detecting circuit 360 detects the phase of the pilot-tone signal PLT and controls the A/D conversion
15 timing of the A/D converter 80. As a result, the A/D conversion and other processing can be executed on the receiving side in sync with the pilot-tone signal.

(e) Sending/receiving of phase of ISDN 400-Hz
signal

20 At the time of training, the training-signal generating circuit 330 transmits a tone signal separately of the pilot-tone signal PLT by carrier #48 to thereby report the phase of the ISDN 400-Hz signal (the transmit phase of the TDD-xDSL on the office side)
25 from the office side to the subscriber side (see Figs. 7 and 8).

In a case where the transmit symbol sequence of one burst contains four training symbols, a tone signal

indicating the phase of the ISDN 400-Hz signal is transmitted by causing the phase of adjacent training symbols in one burst to change at least one time.

Fig. 7 (a) illustrates an example in which the
5 phase of adjacent symbols is caused to change one time in one burst. Here the pattern of the first and second symbols and the pattern of the third and fourth symbols changes from A to B. The symbol patterns can also be changed between the first and second symbols and between
10 the third and fourth symbols. The symbol patterns A and B can be selected in such a manner that the phase difference between them becomes 90° , as shown in the QAM constellation diagram of Fig. 8 (a), or in such a manner that the phase difference between them becomes 180° , as
15 shown in the QAM constellation diagram of Fig. 8 (b).

Fig. 7 (b) illustrates an example in which the phase of adjacent symbols is caused to change twice in one burst. Here the first and second symbol patterns in the manner $B \rightarrow A$ and the third and fourth symbol
20 patterns change in the manner $A \rightarrow B$. The phase-change points may be chosen in such a manner that the patterns change between any two sets of adjacent symbols.

In order to report the phase of the ISDN 400-Hz signal (the transmit phase of the TDD-xDSL on the office
25 side) by the pattern change of Fig. 7 (a), the training-signal generating circuit 330 generates data in such a manner that the symbol data changes in the manner $A \rightarrow A \rightarrow B \rightarrow B$ based upon the rising edge of the ISDN 400-Hz

signal TTR that enters from the sequencer 310. This data is subjected to IFFT processing by the IFFT circuit 30 and becomes the training symbol sequence of Fig. 7 (a), which is then transmitted. On the receiving side, therefore, the time at which the $A \rightarrow B$ phase change occurs is detected and a time which precedes this phase-change time by the time period $T1$ is recognized as being the phase of the rising edge of the ISDN 400-Hz signal TTR. In actuality, the phase of the rising edge of the ISDN 400-Hz signal TTR is decided based upon average values obtained a plurality of times.

In order to report the phase of the ISDN 400-Hz signal (the transmit phase on the office side) by the pattern change of Fig. 7 (b), the training-signal generating circuit 330 generates data in such a manner that the symbol data changes in the manner $B \rightarrow A \rightarrow A \rightarrow B$ based upon the rising edge of the ISDN 400-Hz signal TTR that enters from the sequencer 310. This data is subjected to IFFT processing by the IFFT circuit 30 and becomes the training symbol sequence of Fig. 7 (b), which is then transmitted. On the receiving side, therefore, the times at which the $B \rightarrow A$, $A \rightarrow B$ phase changes occur are detected, the average T_{avr} of these times is obtained and a time which precedes this average time by the set time period $T2$ is recognized as being the time of the rising edge of the ISDN 400-Hz signal TTR. In actuality, the phase of the rising edge of the ISDN 400-Hz signal TTR is decided based upon average

values obtained a plurality of times. In the example of Fig. 7 (b), two phase-change times can be detected by a single training. In comparison with Fig. 7 (a), therefore, the phase of the rising edge of the ISDN 400-
5 Hz signal TTR can be decided by a smaller number of operations.

With G.lite also, which likewise is an xDSL scheme, a method of conveying a change in phase by a tone signal other than a pilot tone is used. In the present
10 invention, however, a transmission in the NEXT interval is not carried out, unlike the case with G.lite. As a consequence, it is unnecessary to distinguish between the FEXT and NEXT intervals and therefore the method in which phase is changed can use a 180° change in addition
15 to the 90° change or a combination of these changes.

(C) First embodiment of burst frames at training time and normal communication time

G992.2 (G.lite) technology is available as a conventional xDSL scheme. With G.lite, 4.3125 kHz is
20 used as the carrier frequency spacing, 256 as the number of samples within one DMT, and #64 as the carrier which transmits the pilot tone. According to the first embodiment of the present invention, 4 kHz, which is lower than in the G.lite scheme, is used as the carrier
25 frequency spacing. As for the other items, 256 is selected as the number of samples in one DMT symbol and #64 is selected as the carrier which transmits the pilot tone, just as in the G.lite scheme.

In the first embodiment, the FFT sampling frequency of the transmitted signal is 1024 kHz in view of the carrier frequency spacing and number of samples. Further, the frequency of the pilot tone is $4 \text{ kHz} \times 64 =$
5 256 kHz. In other words, the data per cycle of the pilot tone is four sample's worth. Further, in the first embodiment, the symbol length of one symbol is 256 samples and the cycle is 250 μs . In view of the relationship with respect to the burst interval of 1250
10 μs in an ISDN ping-pong transmission system, the number of symbols contained in one burst is four at most. If the number of symbols is four, this leaves about 250 μs extra. This extra period of time can be utilized to add on the redundancy signals or set the margins. That is,
15 even if the redundancy signals 503, 504 are added onto the beginning and end of the training symbol sequence, four symbols can be sent without reducing the number of symbols per burst.

(a) Signal transmit interval at normal
20 communication time

The transmit interval of a transmit frame at the time of normal communication according to the first embodiment will be described with reference to Fig. 1. The symbol 701 with the cyclic prefix (CP) 702 is used
25 at normal communication time in TDD-xDSL transmission. The length of the cyclic prefix can be any length as long as the transmit symbol sequence fits within the transmit interval. In this embodiment, however, the

length of the cyclic prefix is made 16 samples (15.635 μ s), which is the same as that in the G992.2 (G.lite) scheme that is one xDSL scheme, and four symbols with a cyclic prefix are connected to construct the transmit
5 symbol sequence 700. The symbol length of the transmit symbol sequence 700, therefore, is 1088 samples (1.0625 ms).

Fig. 18 illustrates the timing relationship between the transmit symbol sequence 700 for normal
10 communication and a signal in ISDN ping-pong transmission.

The transmit interval of a downstream signal will be considered first. In order to arrange it so that the TDD-xDSL transmit interval will not overlap the receive
15 interval of an ISDN ping-pong transmission with certainty, the downstream-signal transmit interval of the TDD-xDSL is placed approximately at the center of the transmit interval of the ISDN ping-pong transmission. It is required that the relation

20
$$S_2 + \alpha_2 + \beta_2 \leq D + a$$

be satisfied as described in accordance with Fig. 3, where the transmit interval D of an ISDN ping-pong transmission is equal to 1.178125 ms (1206.4 samples) and the length S_2 of the TDD-xDSL transmit signal is
25 equal to 1.0625 ms (1088 samples). If the a' which will satisfy $a' < a$ is 9.375 (9.6 samples) allowing for margins, then it will suffice to find the α_2 , β_2 that satisfy

$$S2 + \alpha2 + \beta2 \leq D + a' \leq D + a$$

Since TDD-xDSL downstream transmit interval is brought to the center of the ISDN ping-pong downstream transmit interval, we find that $\alpha2 = \beta2 = 62.5 \mu\text{s}$ (64 samples).

5 Similarly, consider the upstream signal interval. Guard time b between downstream signal reception and upstream signal transmission in ISDN ping-pong transmission is a value having a range of $18.75 \mu\text{s}$ (19.2 samples) to $23.4378 \mu\text{s}$ (24 samples).

10 Since the guard time is a value decided independently of the TDD-xDSL scheme, the transmit interval of the TDD-xDSL upstream transmit symbol sequence cannot be brought exactly to the center of the upstream transmit interval of the ISDN ping-pong transmission. Accordingly, to bring the transmit
15 interval of the TDD-xDSL upstream transmit symbol sequence approximately to the center of the upstream transmit interval of the ISDN ping-pong transmission, the guard time of the ISDN ping-pong transmission is
20 regarded as being $18.75 \mu\text{s}$ (19.2 samples), in which case a TDD-xDSL guard time c is selected in such a manner that end time tge1 of the TDD-xDSL guard time and end time teg2 of the ISDN guard time will approximately coincide.

25 In the first embodiment, (upstream transmit interval of ISDN ping-pong transmission + guard time b) is $1196.875 \mu\text{s}$ and (TDD-xDSL upstream-signal transmit interval $S2$ + beginning and end margins $\alpha2 + \beta2$) is

1187.5 μ s (1216 samples). Accordingly, guard time c of the TDD-xDSL transmission is selected to be 9.765625 - 14.64844 (10 ~ 15 samples) and transmit timing is decided in a manner similar to that of the downstream
5 signal.

(b) Signal transmit interval at training time

The signal transmit interval at the time of training according to the first embodiment will be described with reference to Figs. 17 and 19. Fig. 17
10 illustrates the transmit symbol sequence 500 for TDD-xDSL training. It is desired that the redundancy signal 503 added onto the beginning of four successive training symbols 501 be a sufficiently long interval relative to the cyclic prefix 702 at the time of normal
15 communication. It will be assumed here that a redundancy signal 503 of 125 μ s (128 samples), which is a sufficiently long interval relative to a cyclic prefix having a length of 16 samples (15.625 μ s), is used as an example. Further, a redundancy signal of eight samples
20 (7.8125 μ s) is added on as an example of the redundancy signal 504 added on at the end of the four training symbols. Thus is constructed the transmit symbol sequence 500 for training. As a result, we have $x1 = 125 \mu$ s (128 samples), $y1 = 7.8125 \mu$ s (eight samples).
25 Further, we have $S1 = 1$ ms (1024 samples = 256×4).

From this we obtain

$$S1 + x1 + y1 = 1.132813 \text{ ms (1160 samples).}$$

Next, if we find $(S1 + \alpha1 + \beta1 + x1 + y1)$ which falls

within $D + a'$ in a manner similar to that at normal communication time, as shown in Fig. 19, we have

$$1.132813 \text{ ms (1160 samples)} + \alpha_1 + \beta_1 \leq 1.1875 \text{ ms} \\ (1216 \text{ samples})$$

- 5 Accordingly, $\alpha_1 = 0 \text{ } \mu\text{s}$ (zero samples), $\beta_1 = 54.6875 \text{ } \mu\text{s}$ (56 samples) is selected.

(c) Consideration of worst conditions

Transmission delay in an ISDN ping-pong system and transmission delay in a TDD-xDSL system are decided
10 separately and independently. As a consequence, in a case where an ISDN line is nearby (no delay) and a TDD-xDSL is most remote (maximum delay), there will be instances where, at training time, transmission of an upstream signal from the subscriber side of the ISDN
15 starts before the end of reception of a downstream signal of the TDD-xDSL on the subscriber side, resulting in a discrepancy between the transmit and receive timings. Accordingly, consider the worst conditions of a TDD-xDSL transmission transmit/receive interval with
20 respect to an ISDN transmit/receive interval. In the first embodiment, the length of the TDD-xDSL transmission symbol sequence is greater at training time (i.e., 1160 samples) than at normal communication time (i.e., 1088 samples). Accordingly, consideration will
25 be given to training time.

(c-1) First worst condition

A worst condition which will be discussed first is a case where the delay time of a TDD-xDSL transmission

is minimum and the delay time of an ISDN ping-pong transmission is maximum. As shown in Fig. 20, the start of transmission of an upstream signal in TDD-xDSL transmission must not occur before ISDN transmission of a downstream signal ends. In the first embodiment, the latest timing of the end of reception of an ISDN downstream signal is that obtained by adding a transmission delay of 50 μ s (51.2 samples) to the length of 1.178125 ms (1206.4 samples) of the ISDN downstream transmit signal.

On the other hand, the earliest timing of the start of transmission of a TDD-xDSL transmit signal is the total obtained by adding beginning and end margin intervals $\alpha_1 = 0$ μ s (zero samples), $\beta_1 = 54.6875$ μ s (56 samples), which precede and follow signal transmission, to the TDD-xDSL downstream signal interval of 1.132813 ms (1160 samples) and then adding on the upstream-downstream guard time and beginning margin interval $\alpha_1 (= 0)$, which precedes signal transmission. A guard time of 44.92188 to 49.80469 μ s (46 to 51 samples) between upstream and downstream TDD-xDSL transmissions is decided in such a manner that the following will hold:

$$\begin{aligned} &\text{end of ISDN downstream signal interval} < \\ &\text{beginning of TDD-xDSL upstream signal} \end{aligned}$$

As a result, we have

$$\begin{aligned} &1.228125 \text{ ms (1257.6 samples) [end of ISDN} \\ &\text{downstream signal interval]} < 1.232422 \text{ ms (1262} \\ &\text{samples) [beginning of TDD-xDSL upstream signal]} \end{aligned}$$

Thus the TDD-xDSL upstream signal will not be transmitted earlier than the end of reception of the ISDN downstream signal. In other words, even under the worst condition set forth above, the transmit interval of the TDD-xDSL transmission falls within the transmit interval of the ISDN unit on the side near the transmitting ADSL unit.

(c-2) Second worst condition

A worst condition which will be described next is the converse of the above, i.e., a case where the delay time of a TDD-xDSL transmission is maximum and the delay time of an ISDN ping-pong transmission is minimum. In this case, as shown in Fig. 21, the end of the receive interval of the TDD-xDSL downstream signal must end before the beginning of transmission of the ISDN upstream signal. In the first embodiment, the latest timing of the end of reception of the TDD-xDSL downstream signal is obtained by adding the length of 1132.813 μ s (1160 samples) of the TDD-xDSL downstream transmit signal, a transmission delay time of 57.8125 μ s (59.2 samples), a margin of 4.882813 μ s (five samples) for a shift in receive timing and the margin interval α_1 (= 0) μ s (zero samples) that precedes signal transmission.

On the other hand, the earliest transmit timing of the upstream signal in ISDN ping-pong transmission is the result (= 1.196875 ms) of adding the minimum upstream-downstream guard time of 18.75 μ s (19.2

samples) to the ISDN downstream interval of 1.178125 ms.

Comparing this with the foregoing, we have

1.195508 ms (1224.2 samples) [end of TDD-xDSL
downstream signal interval] < 1.196875 ms (1225.6
5 samples) [beginning of ISDN upstream signal]

Thus the TDD-xDSL downstream signal is received earlier
than the start of transmission of the ISDN upstream
signal. As a result, even under the second worst
condition set forth above, the transmit interval of the
10 ISDN upstream signal will not overlap the receive
interval of the TDD-xDSL downstream signal.

(c-3) Third worst condition

Reference will be had to Fig. 22 to describe that
in a case where the delay time of TDD-xDSL transmission
15 is maximum, the receive interval of a TDD-xDSL upstream
signal will not overlap the transmit interval of a
downstream signal in ISDN ping-pong transmission.

The end of the TDD-xDSL upstream receive signal is
2.492578 ms, which is obtained by adding (1) a transmit
20 interval of 1.132813 ms (1160 samples) of the TDD-xDSL
downstream signal, (2) a beginning margin interval of α_1
= 0 μ s (= zero samples) and (3) an end margin interval
of β_1 = 54.6875 μ s (56 samples), which precede and
follow the signal transmission, (4) a transmission delay
25 of 57.8125 μ s (59.2 samples) \times 2 (because of the two
directions, namely upstream and downstream), (5)
summation of an upstream-downstream maximum guard time
of 49.80469 μ s (51 samples) and a margin of 4.882813 μ s

(5 samples) for the shift of receive timing, (6) the transmit interval of 1.132813 ms (1160 samples) of the TDD-xDSL upstream signal, (7) a margin interval of $\alpha_1 = 0 \mu s$ (zero samples) that precedes the transmission of the signal and (8) a margin of 0.976567 (one sample) $\times 2$, which is for a delay in rise time when the DMT symbol starts to be sent or a remaining signal when transmission of the DMT symbol is stopped, On the other hand, the burst cycle of the ISDN ping-pong transmission is 2.5 ms. Comparing this with the foregoing, we have

$$2.492578 \text{ ms (2552.4 samples) [end of TDD-xDSL upstream signal interval]} < 2.5 \text{ ms (2560 samples) [ISDN burst cycle]}$$

Thus the reception of the TDD-xDSL upstream ends earlier than the start of transmission of the next ISDN downstream signal. In other words, even if the delay time of the TDD-xDSL transmission is maximum, the receive interval of the TDD-xDSL upstream signal will not span the ISDN transmit interval of the next burst.

The foregoing is a review of worst conditions. However, in a case where an ISDN line and a TDD-xDSL metallic line are adjacent to each other, these are connected to the same office and therefore the worst conditions are not possible in actuality.

For example, in a case where an ISDN line has no transmission delay time and the transmission delay time of a TDD-xDSL is maximum, the ISDN unit DSU on the

subscriber side is disposed alongside the central office CN and the TDD-xDSL unit xTU-R on the subscriber side is disposed at a location remote from the central office, as shown in (a) of Fig. 23. In a case where an upstream
5 signal from the ISDN unit DSU leaks into the TDD-xDSL under these circumstances, the fact that noise is transmitted from the location at which the ISDN unit DSU is disposed to the location at which the TDD-xDSL unit xTU-R is disposed results in a transmission delay. If
10 the transmission of the downstream TDD-xDSL signal from the office side has ended, therefore, the upstream signal of the ISDN line will be unaffected.

Conversely, in a case where the transmission delay time of the ISDN line is maximum and the TDD-xDSL has no
15 transmission delay, the ISDN unit DSU on the subscriber side is disposed at a location remote from the central office CN and the TDD-xDSL unit xTU-R on the subscriber side is disposed at a location alongside the central office, as shown in (b) of Fig. 23. In this case also
20 the fact that the upstream signal of the TDD-xDSL transmission leaks into the ISDN unit DSU on the subscriber side as noise results in transmission delay. If the transmission of the ISDN downstream signal from the office side has ended, therefore, the ISDN line will
25 be unaffected.

(d) Phase difference between transmit symbol sequences at training time and normal communication time

The phase difference between the transmit symbol sequence for training and the transmit symbol sequence for normal communication time will be described with reference to Fig. 24. The difference between the starting position of the leading symbol 501 at training time and the starting position of the leading symbol 701 from which the cyclic prefix (CP) has been removed at normal communication time is $\theta d1 = 46.875 \mu s$ (48 samples) in case of a downstream signal and $\theta d2 =$
5 82.0312 μs (48 samples) in case of an upstream signal, as will be obvious from Fig. 24.

Since 3.90625 μs (four samples) is one pilot tone cycle, the phase differences $\theta d1$, $\theta d2$ are 12 and 21 times the pilot tone, respectively, and therefore the requirement that the phase differences be a whole-number
15 multiple of the pilot-tone cycle is satisfied.

(2) Second embodiment

As in the case of the G.lite scheme, the second embodiment relates to a case where 4.3125 kHz is selected as the carrier frequency spacing, 256 as the
20 number of samples and #64 as the carrier which transmits the pilot tone.

According to the second embodiment, the sampling frequency is 1104 kHz and the pilot-tone frequency is 276 kHz. Accordingly, 3.623188 μs (four samples)
25 constitutes one pilot tone cycle in a manner similar to that of the first embodiment. Further, in the second embodiment, the length of the cyclic prefix is, e.g.,

28.98551 μ s (32 samples), which is longer than in the case of the G.lite scheme, the length of the redundancy signal 503 added onto the beginning at training time is 115.94203 μ s (128 samples), which is a redundancy length
5 sufficiently longer than the cyclic prefix of the G.lite scheme, and the length of the redundancy signal added on at the end is 18.11594 μ s (20 samples). In view of the foregoing, the structures of the transmit symbol sequences 500, 700 at normal communication time and
10 training time, respectively, are as shown in Fig. 25.

The signal transmit interval at normal communication time in the second embodiment will be described with reference to Fig. 26. If it is so arranged that the TDD-xDSL signal transmit interval is
15 brought to approximately the center of the transmit interval of the ISDN ping-pong transmission in a manner similar to that of the first embodiment, then, if the following hold:

$D + a' = 1.1875$ ms (1311 samples)
20 $S_2 = 1.043478$ ms (1152 samples)
we have $\alpha_1 + \beta_2 = 144.0217$ μ s (159 samples) and therefore $\alpha_2 = 70.65217$ μ s (78 samples) and $\beta_2 = 73.36957$ μ s (81 samples) are selected.

Similarly, the signal transmit interval at training
25 time in the second embodiment is illustrated in Fig. 27.

Since the following hold:

$D + a' = 1.1875$ ms (1311 samples)
 $S_1 + x_1 + y_1 = 1.061594$ ms (1172 samples)

we have $\alpha_1 + \beta_1 = 125.9058 \mu\text{s}$ (139 samples).

Accordingly, if it is so arranged that the TDD-xDSL
signal transmit interval is brought to approximately the
center of the transmit interval of the ISDN ping-pong
transmission in a manner similar to that of the first
embodiment, $\alpha_1 = 63.4057 \mu\text{s}$ (70 samples) and $\beta_1 = 62.5$
 μs (69 samples) are selected.

If the above-described first, second and third
worst conditions are taken into consideration in the
second embodiment, (1), (2) and (3) set forth below will
hold, where the guard time between upstream and
downstream signals is 27.17391 to $31.7029 \mu\text{s}$ (30 to 34
samples):

- (1) 1.228125 ms (1355.85 samples) [latest end of
ISDN downstream signal interval]
 $< 1.27808 \text{ ms}$ (1411 samples) [earliest
beginning of TDD-xDSL upstream signal
interval];
- (2) 1.92029 ms (1316 samples) [latest end of
TDD-xDSL downstream signal interval]
 $< 1.96875 \text{ ms}$ (1321.35 samples) [earliest
beginning of ISDN upstream signal
interval]; and
- (3) 2.475543 ms (2733 samples) [end of
TDD-xDSL upstream signal interval]
 $< 2.5 \text{ ms}$ (2760 samples) [ISDN burst cycle].

In accordance with (1), the upstream signal of the
TDD-xDSL transmission will not be transmitted earlier

than the end of reception of the ISDN downstream signal even under the first worst condition.

In accordance with (2), the TDD-xDSL downstream signal is received earlier than the start of
5 transmission of the ISDN upstream signal under the second worst condition.

In accordance with the (3), reception of the TDD-xDSL upstream signal ends earlier than start of
transmission of the ISDN downstream signal of the next
10 burst.

With reference to Fig. 25, the phase difference between the transmit symbol sequence 700 for normal communication and the transmit symbol sequence 500 at the time of training is $79.71014 \mu s$ (88 samples), which
15 is equal to the pilot-tone cycle $\times 22$. Thus the phase difference is a whole-number multiple of the pilot tone (i.e., 22 times the pilot tone).

Thus, in a digital subscriber line transmission system based upon TDD-xDSL in accordance with the
20 present invention, training for establishing communication can be speeded up, communication reliability can be enhanced and the structure of the communications equipment can be simplified over that of the prior art.

25 More specifically, in accordance with the present invention, it is so arranged that in a TDD-xDSL transmission, a DMT symbol sequence is transmitted upon adding some data that is contained within the DMT symbol.

sequence onto the beginning or end or onto both the beginning and end of the sequence as redundancy data at the time of training, which is carried out before normal communication, and the redundancy data is removed on the receiving side. As a result, distortion develops in the redundancy data but not in the training symbols. This makes it possible to carry out training using all training symbols and to shorten training time.

Further, in accordance with the present invention, the length of the transmit training symbol sequence after the redundancy data is added on is made such that the training symbol sequence will fall within the transmit interval of an ISDN ping-pong transmission. In other words, it is so arranged that the training symbol sequence will not fall within the receive interval (NEXT interval) of an ISDN ping-pong transmission. As a result, communication with an excellent S/N ratio can be performed by eliminating the effects of NEXT from ISDN ping-pong transmission.

Further, in accordance with the present invention, it is so arranged that in a TDD-xDSL transmission, the frequency of a pilot tone serving as a timing regeneration signal is set so as to assure continuity of sample data in contiguous transmit burst symbol sequences, or such that the length of an interval in which there is no transmission of contiguous transmit burst symbol sequences is made a whole-number multiple of the pilot-tone cycle. As a result, the phase of a

pilot tone will not shift between contiguous transmit burst symbol sequences and processing can be executed at an accurate timing on the receiving side.

Further, in accordance with the present invention,
5 it is so arranged that in a TDD-xDSL transmission, the phase difference between the phase of a training symbol onto which a cyclic prefix used in transceiver training has not been added and the phase of a DMT symbol obtained by removing the cyclic prefix at the time of
10 normal data communication is made a whole-number multiple of the pilot-tone cycle used as a timing regeneration signal. As a result, when there is a sequence transition from training to normal data communication, the timing regeneration signal (pilot
15 tone) does not develop a phase shift. This makes accurate processing possible.

Further, in TDD-xDSL transmission according to the present invention, when the subscriber side is notified of transmit timing (the phase of an ISDN 400-Hz signal)
20 of a TDD-xDSL burst signal on the office side, a tone signal the phase whereof varies one or more times within one transmission burst is transmitted separately of the pilot-tone signal, and this change in the phase of the tone signal is detected on the subscriber side to
25 identify the transmit timing of the TDD-xDSL burst signal. As a result, a correct TDD-xDSL transmission can be performed by detecting the transmit timing (the phase of an ISDN 400-Hz signal) at the time of training

of a TDD-xDSL transmission. In this case the phase of the tone signal can be changed 90 or 180°. This makes it possible to recognize transmit timing even if transmit timing (the phase of the ISDN 400-Hz signal) is
5 . unknown initially.

CLAIMS:

1. A digital subscriber line transmission method for alternately transmitting and receiving a DMT symbol sequence between xDSL devices by TDD-xDSL transmission,
5 characterized in that at the time of training for setting up communication, a training-symbol transmitting side adds some data contained in a training symbol sequence of identical patterns onto the beginning or end or onto both the beginning and end of the symbol
10 sequence and transmits the sequence as a continuous training symbol sequence.

2. The digital subscriber line transmission method according to claim 1, characterized in that the data that has been added onto the beginning and/or end of
15 said symbol sequence is removed on a receiving side of the training symbol sequence.

3. The digital subscriber line transmission method according to claim 1 or 2, characterized in that the training symbol sequence is transmitted after the data
20 has been added on upon setting the length thereof in such a manner that the symbol sequence will not fall within a receive interval of an ISDN ping-pong transmission.

4. The digital subscriber line transmission method
25 according to claim 3, characterized in that a transmit signal sequence at time of normal communication is transmitted upon setting the length thereof in such a manner that the symbol sequence will not fall within the

receive interval of the ISDN ping-pong transmission; and

the length of a cyclic prefix added onto the beginning of each symbol which constructs said transmit symbol sequence is made shorter than that of the data portion that has been added onto the beginning of the training symbol sequence.

5 5. A digital subscriber line transmission method for alternately transmitting and receiving a DMT symbol sequence between xDSL devices by TDD-xDSL transmission, characterized in that frequency of a pilot-tone signal used as a timing regeneration signal is set so as to assure continuity of sample data in contiguous transmit burst symbol sequences, or length of an interval in which a signal is not being transmitted between
10 contiguous transmit burst symbol sequences is made a whole-number multiple of the cycle of a pilot-tone signal.

6. A digital subscriber line transmission method for alternately transmitting and receiving a DMT symbol
20 sequence between xDSL devices by TDD-xDSL transmission, characterized in that phase difference between a training symbol onto which a cyclic prefix has not been added and a symbol obtained by removing the cyclic prefix from a symbol onto which the cyclic prefix has
25 been added at time of normal data communication is made a whole-number multiple of the cycle of pilot-tone signal used as a timing regeneration signal.

7. A digital subscriber line transmission method for

alternately transmitting and receiving a DMT symbol sequence between xDSL devices by TDD-xDSL transmission, characterized by:

5 sending a tone-signal for notifying a subscriber side of transmit timing of a TDD-xDSL burst signal on the office side; and

notifying the subscriber side of the transmit timing of the TDD-xDSL burst signal by varying the phase of said tone-signal one or more times within one
10 transmission burst.

8. A digital subscriber line transmission method according to claim 7, characterized in that the subscriber side detects variation in the phase of said tone-signal to thereby identify the transmit timing of
15 the TDD-xDSL burst signal on the office side.

9. A digital subscriber line transmission method according to claim 7, characterized in that the phase of the tone-signal is varied by varying the phase of adjacent symbols, which construct a training symbol
(sequence, by 90 or 180°.
20

10. A digital subscriber line transmission apparatus for alternately transmitting and receiving a DMT symbol sequence between xDSL devices by TDD-xDSL transmission, characterized by having a transmitting unit for adding
25 some data contained in a training symbol sequence onto the beginning or end or onto both the beginning and end of the symbol sequence and transmitting the sequence at training time carried out prior to normal communication..

11. The apparatus according to claim 10, characterized by having a receiving unit for carrying out training upon removing data that has been added onto a received training symbol.
- 5 12. The apparatus according to claim 10, characterized in that said transmitting unit has a transmission controller for setting the length of a transmit training symbol sequence after data has been added thereon in such a manner that the symbol sequence will not fall
10 within a receive interval of an ISDN ping-pong transmission and for transmitting the transmit training symbol sequence.
13. The apparatus according to claim 12, characterized in that said transmission controller makes the length of
15 an interval in which a signal is not transmitted between contiguous transmit burst symbol sequences a whole-number multiple of the cycle of a pilot-tone signal.
14. The apparatus according to claim 12, characterized in that said transmission controller makes a phase
20 difference between a training symbol onto which a cyclic prefix has not been added and a symbol obtained by removing the cyclic prefix from a symbol onto which the cyclic prefix has been added at time of normal data communication a whole-number multiple of the cycle of
25 pilot-tone signal used as a timing regeneration signal.
15. The apparatus according to claim 10, characterized by having transmit timing notification means for notifying a subscriber side of transmit timing of the

TDD-xDSL burst signal by varying the phase of a tone-signal one or more times within one transmission burst.

16. The apparatus according to claim 15, characterized in that the transmit timing notification means varies
5 the phase of the tone by varying the phase of adjacent symbols, which construct a training symbol sequence, by 90 or 180°.

ABSTRACT

In a digital subscriber line transmission method for alternately transmitting and receiving a DMT symbol sequence between xDSL devices by TDD-xDSL transmission, 5 a training-symbol transmitting side adds some data contained in a DMT symbol sequence onto the beginning or end or onto both the beginning and end of the symbol sequence redundantly and transmits the sequence at the time of training carried out prior to normal 10 communication. A receiving side of the training symbol sequence performs training upon removing redundant data that has been added onto the beginning and end of the symbol sequence.

FIG. 1

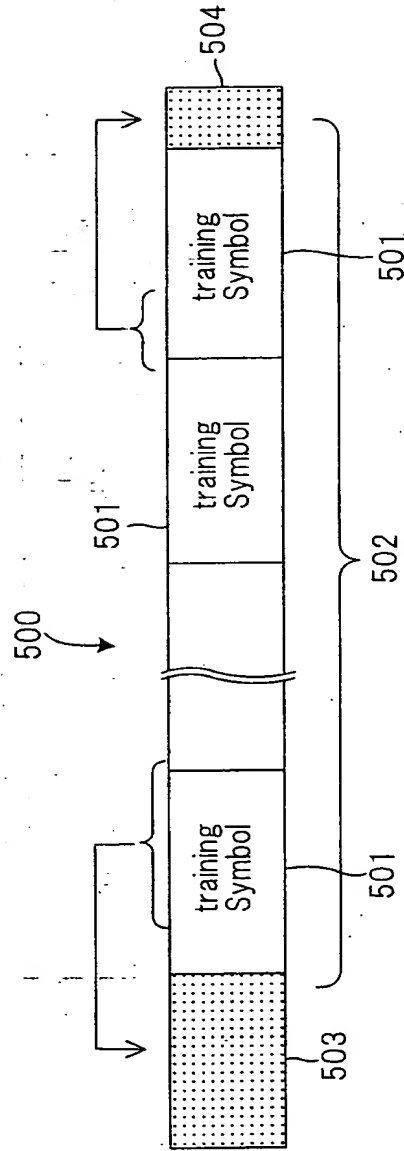


FIG. 2

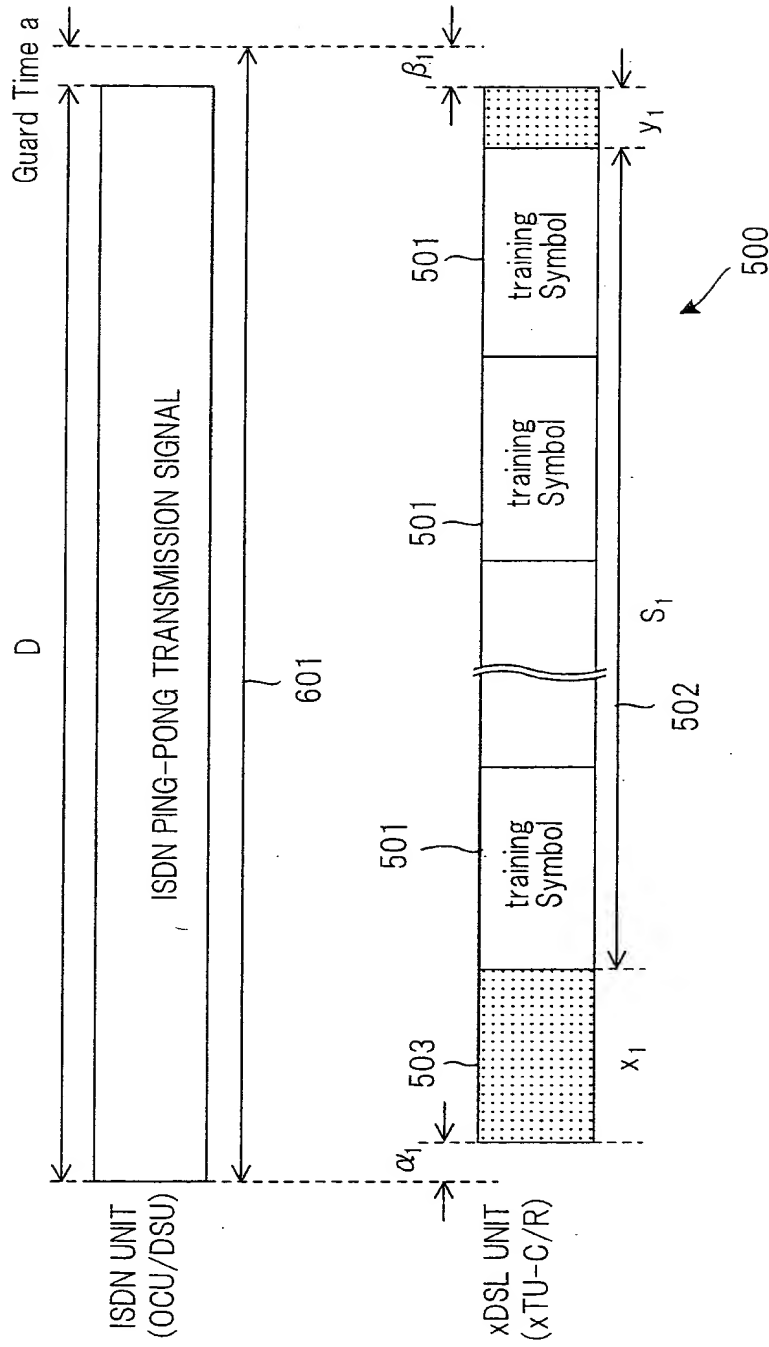


FIG. 3

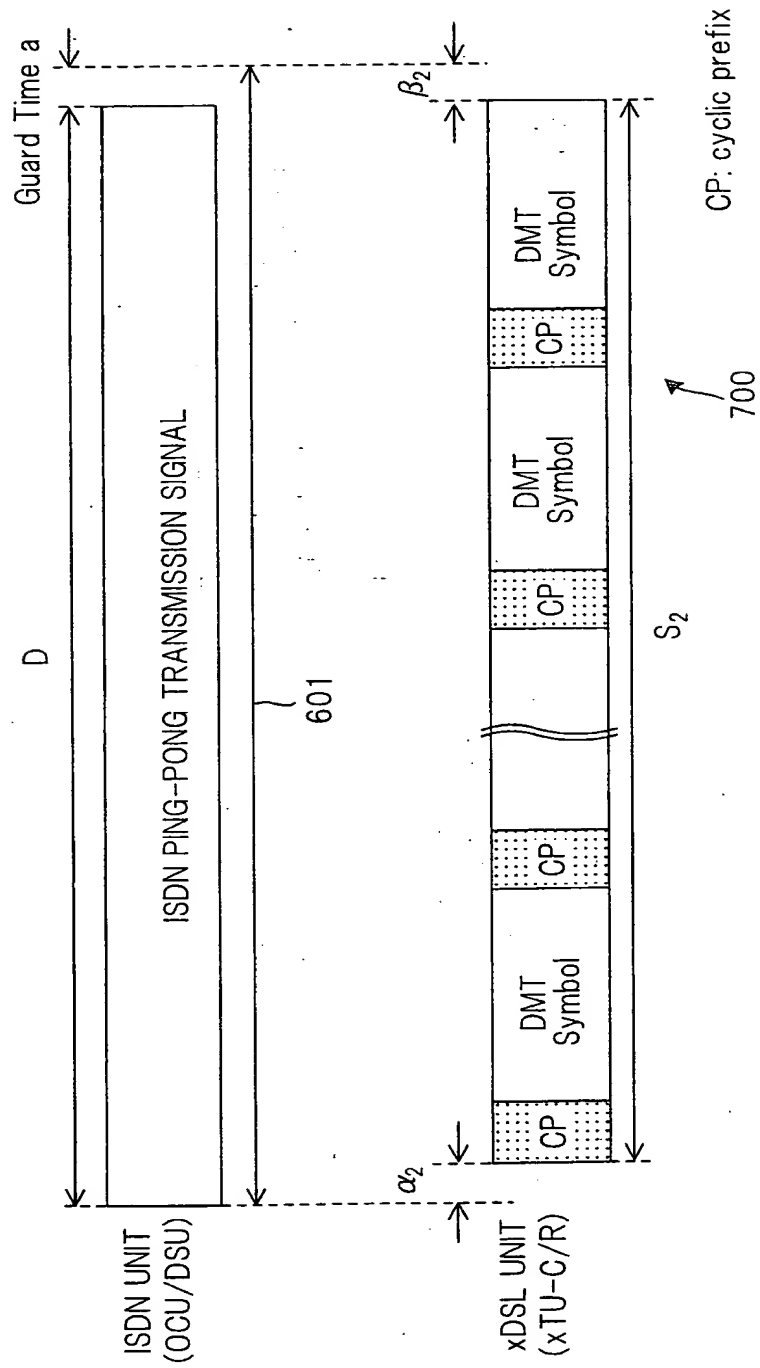


FIG. 4

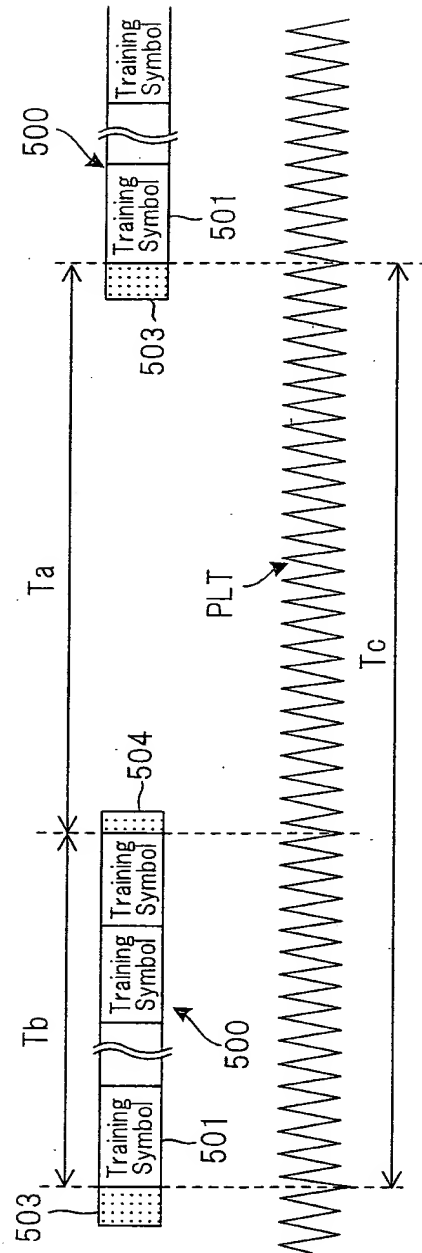


FIG. 6

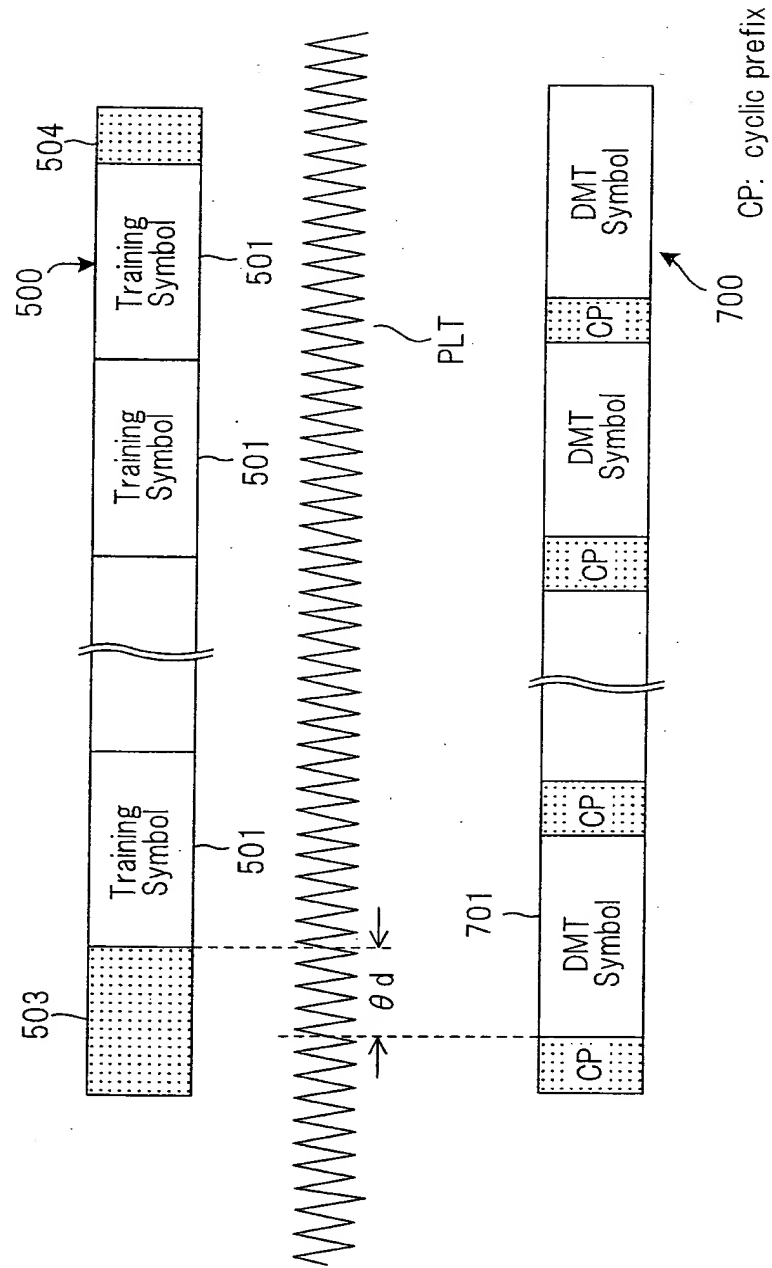


FIG. 7

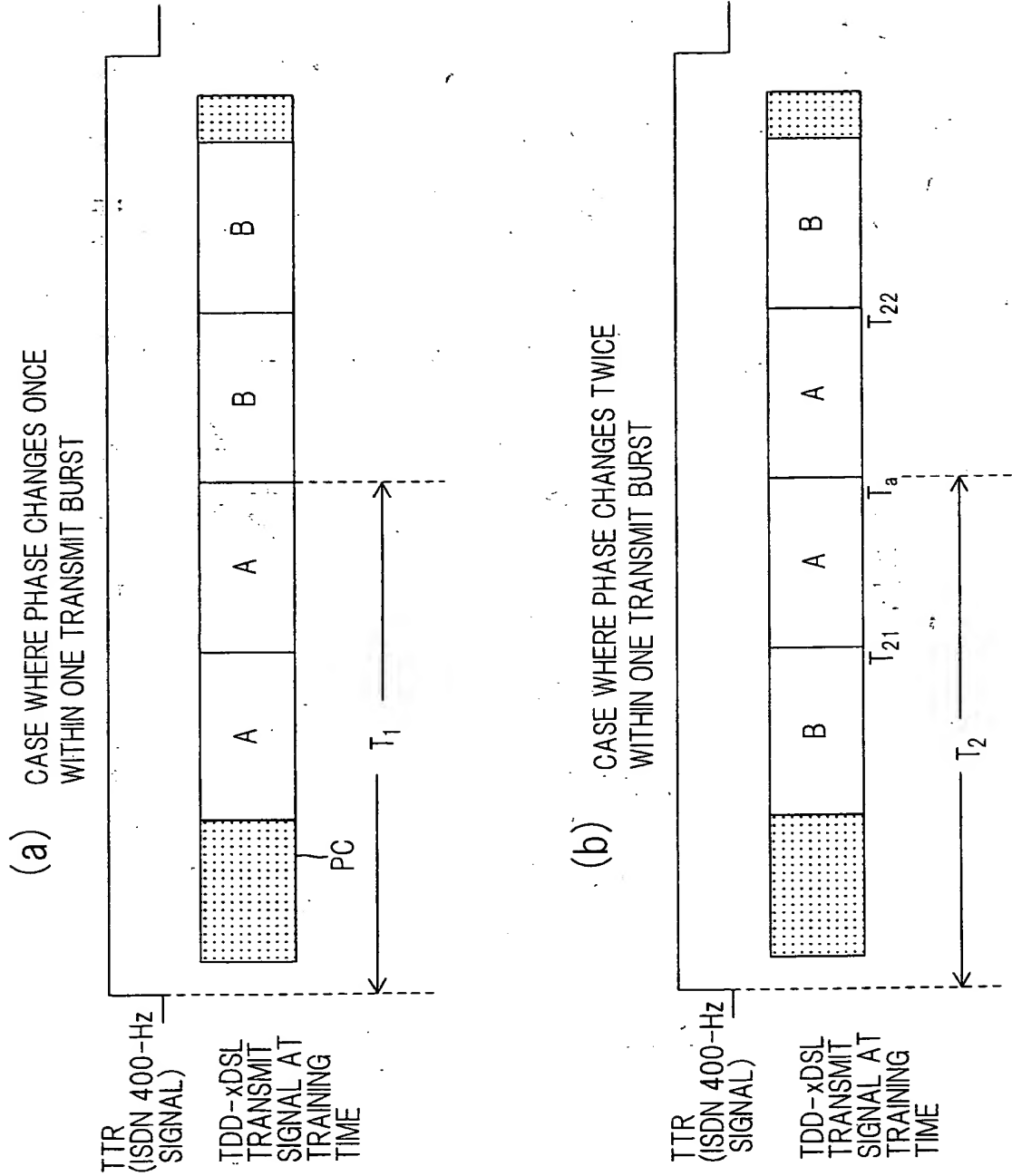
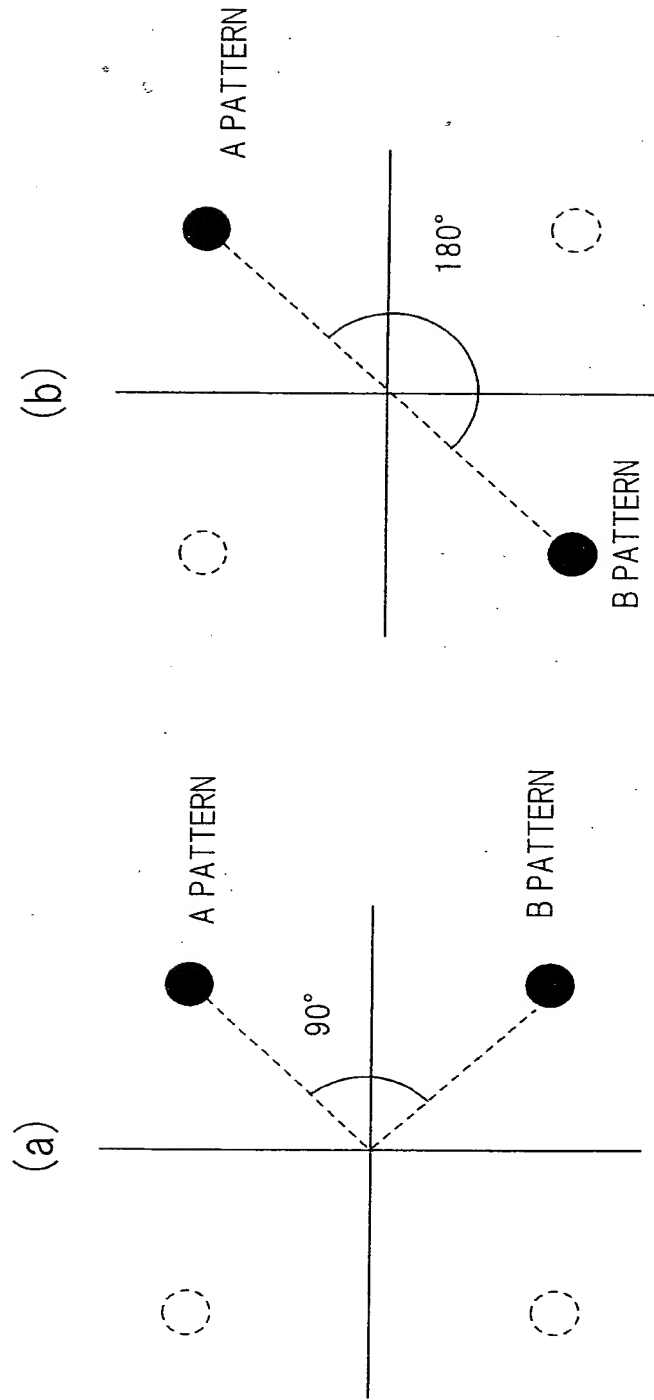


FIG. 8



TRANSMIT PATTERN 1 PER TRAINING SYMBOL

TRANSMIT PATTERN 2 PER TRAINING SYMBOL

FIG. 10

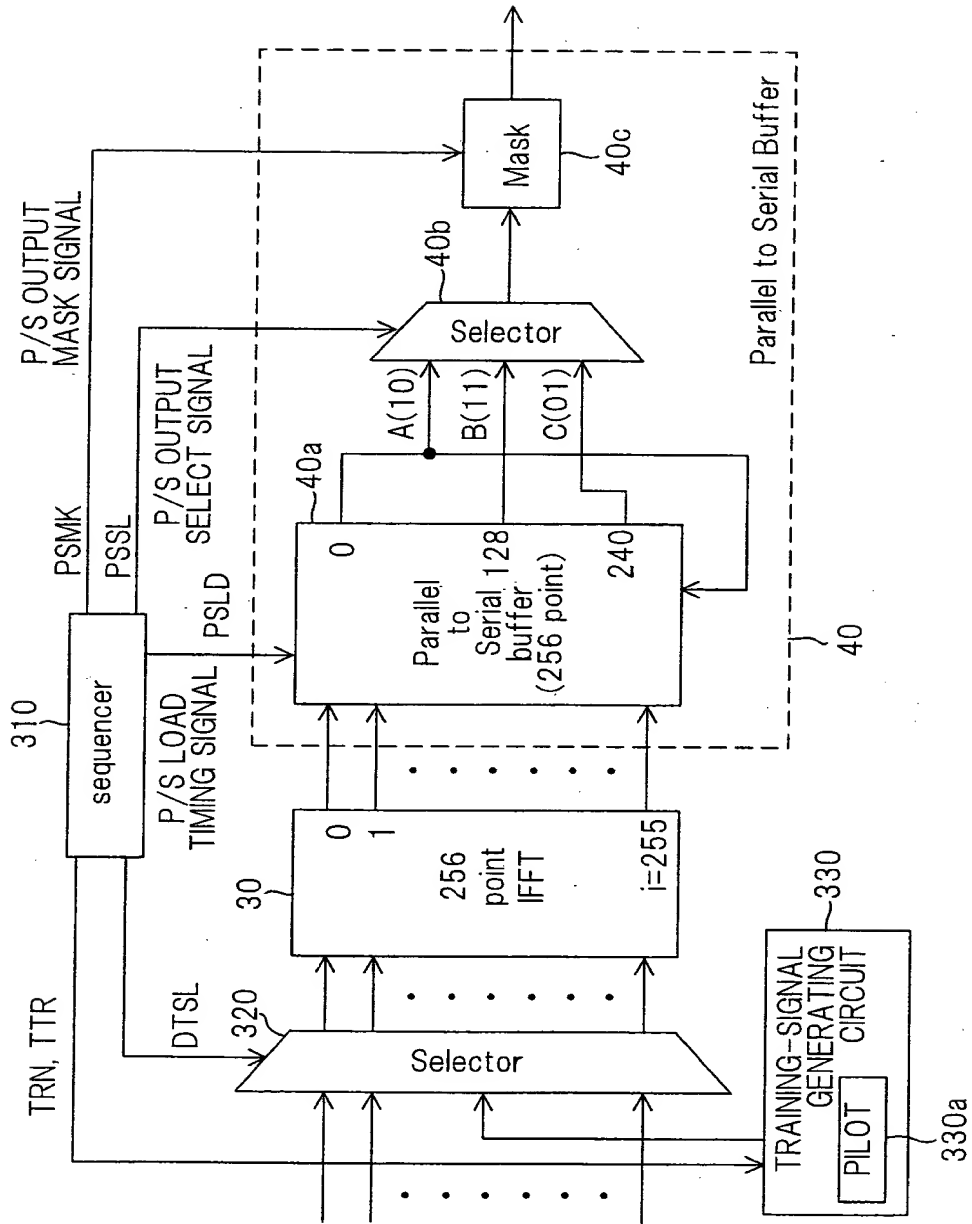


FIG. 11

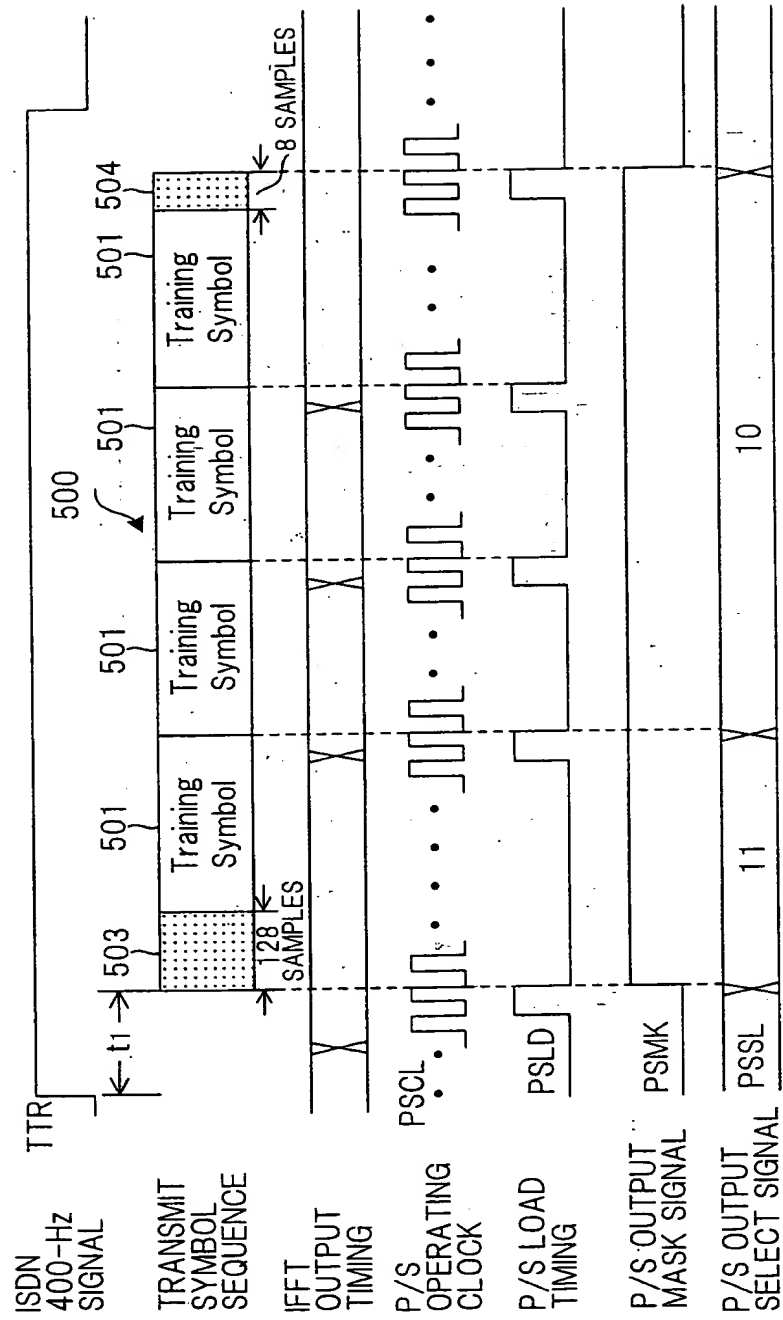
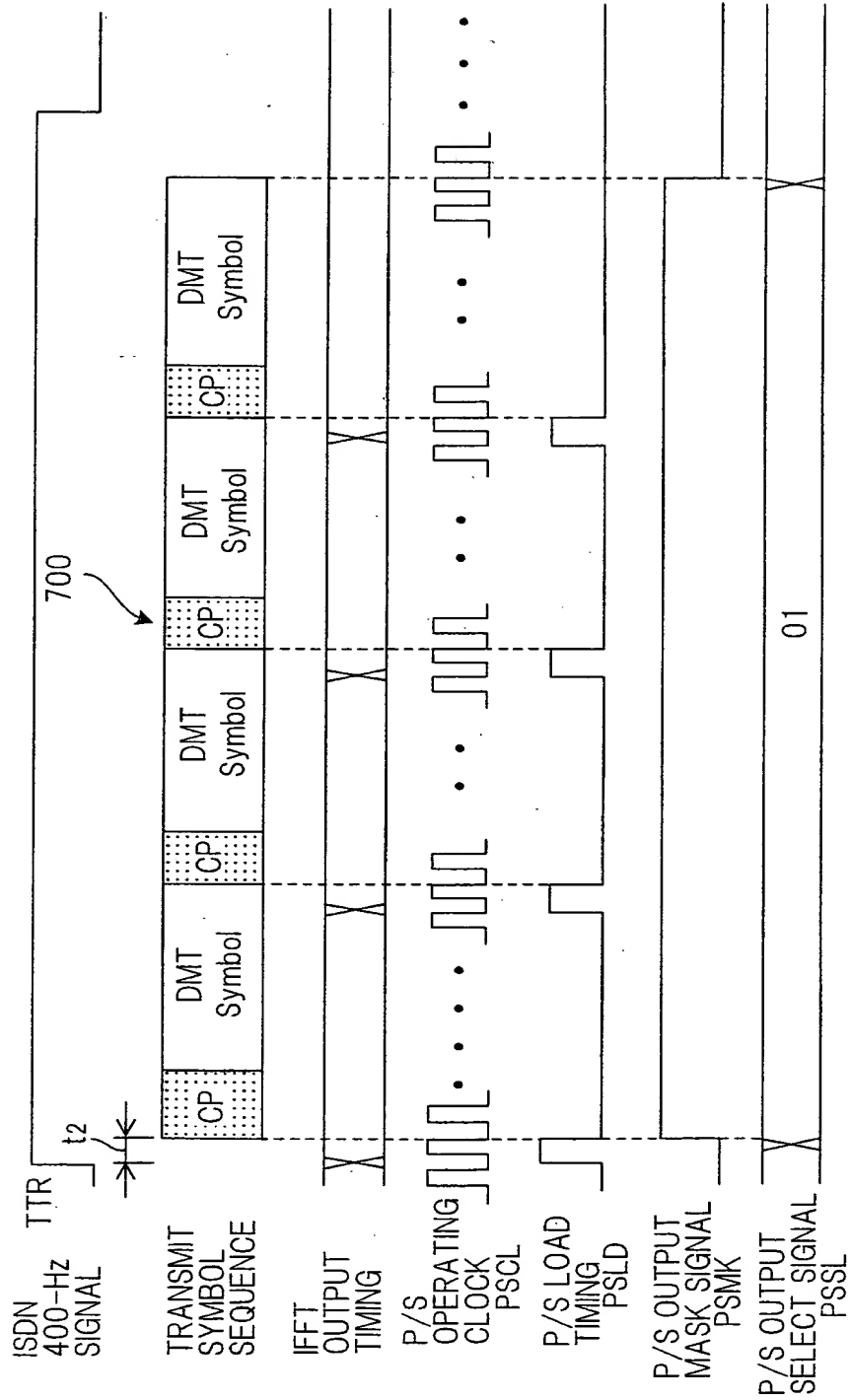


FIG. 12



CP: cyclic prefix

FIG. 13

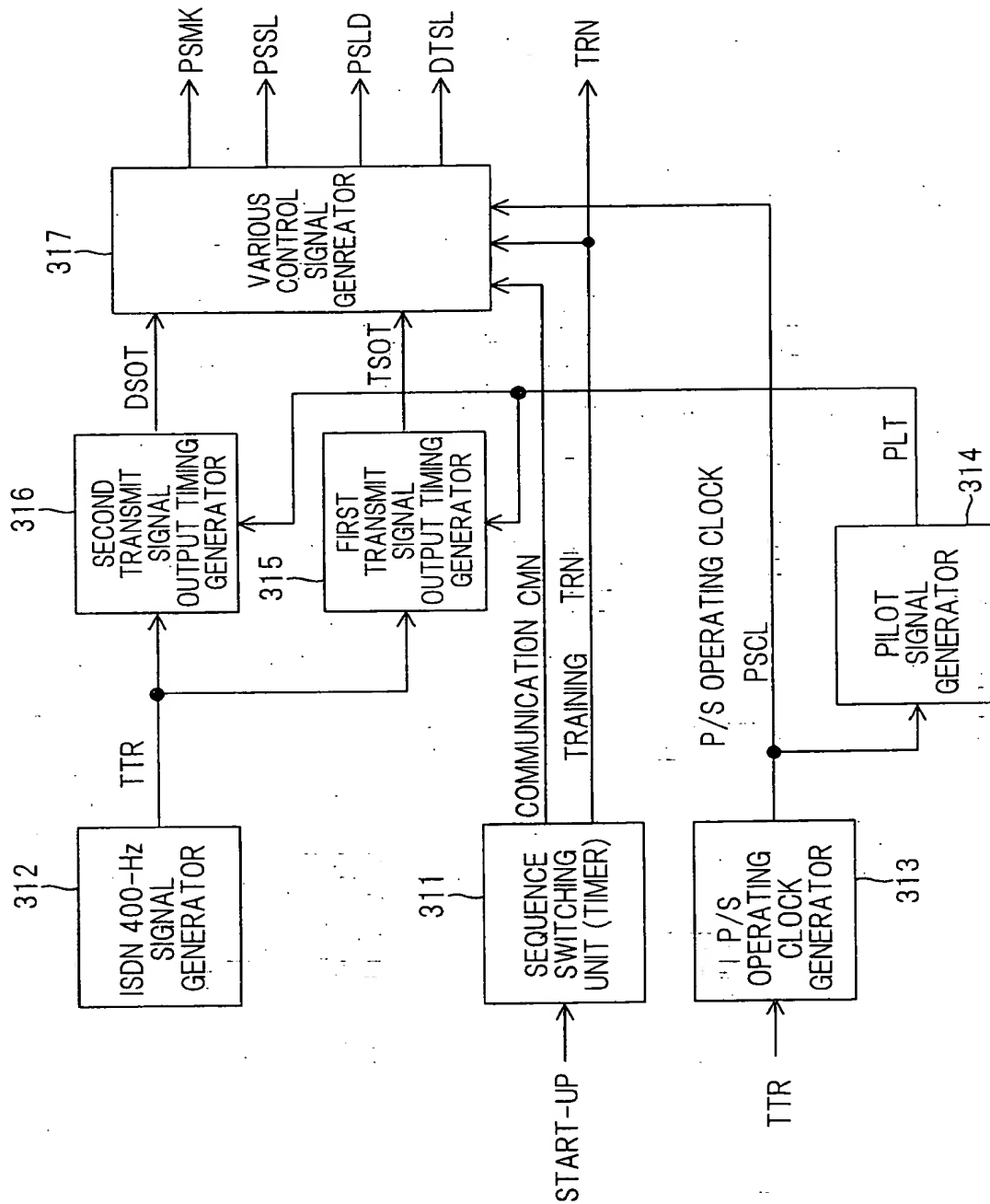


FIG. 14

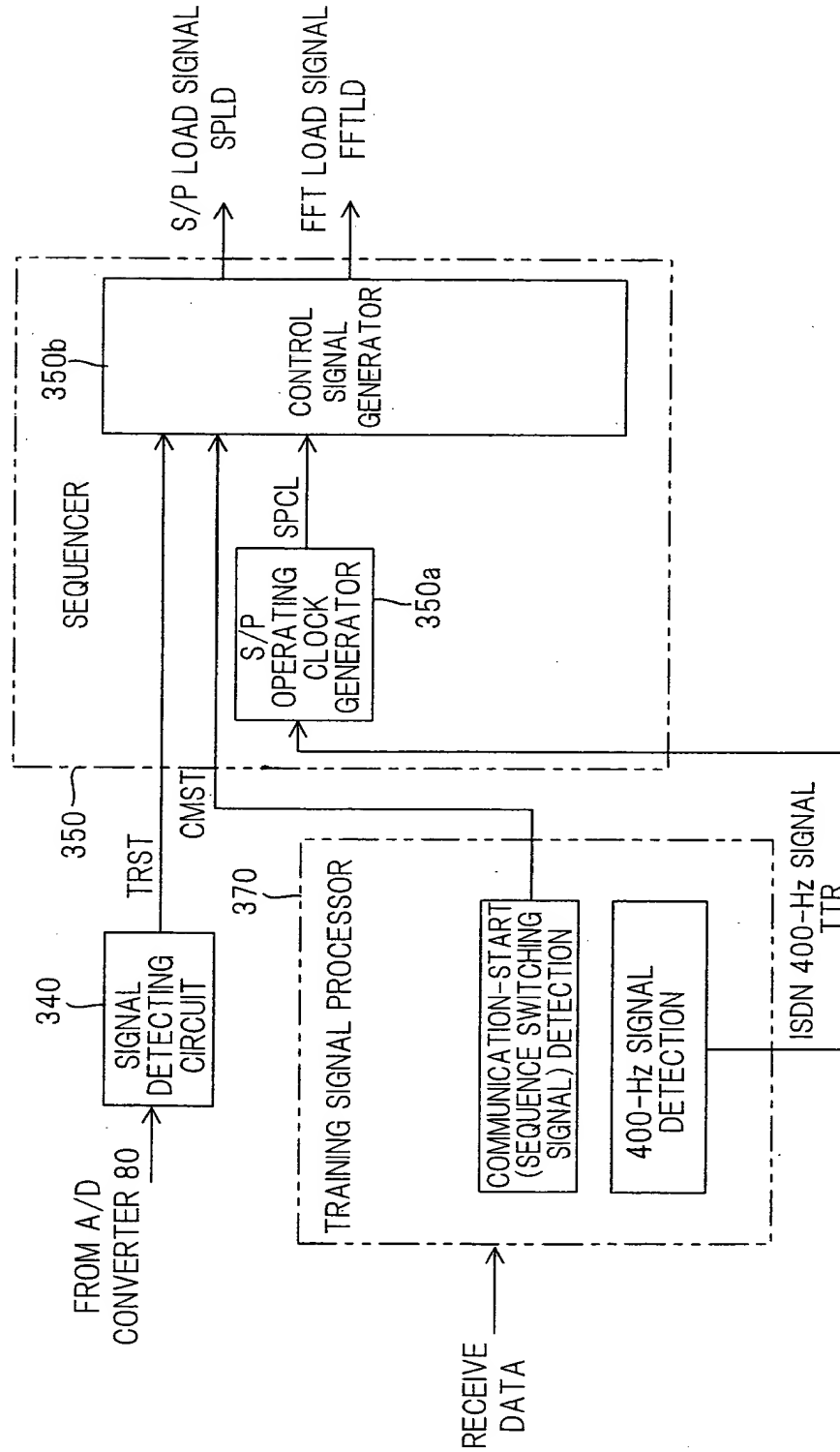


FIG. 15

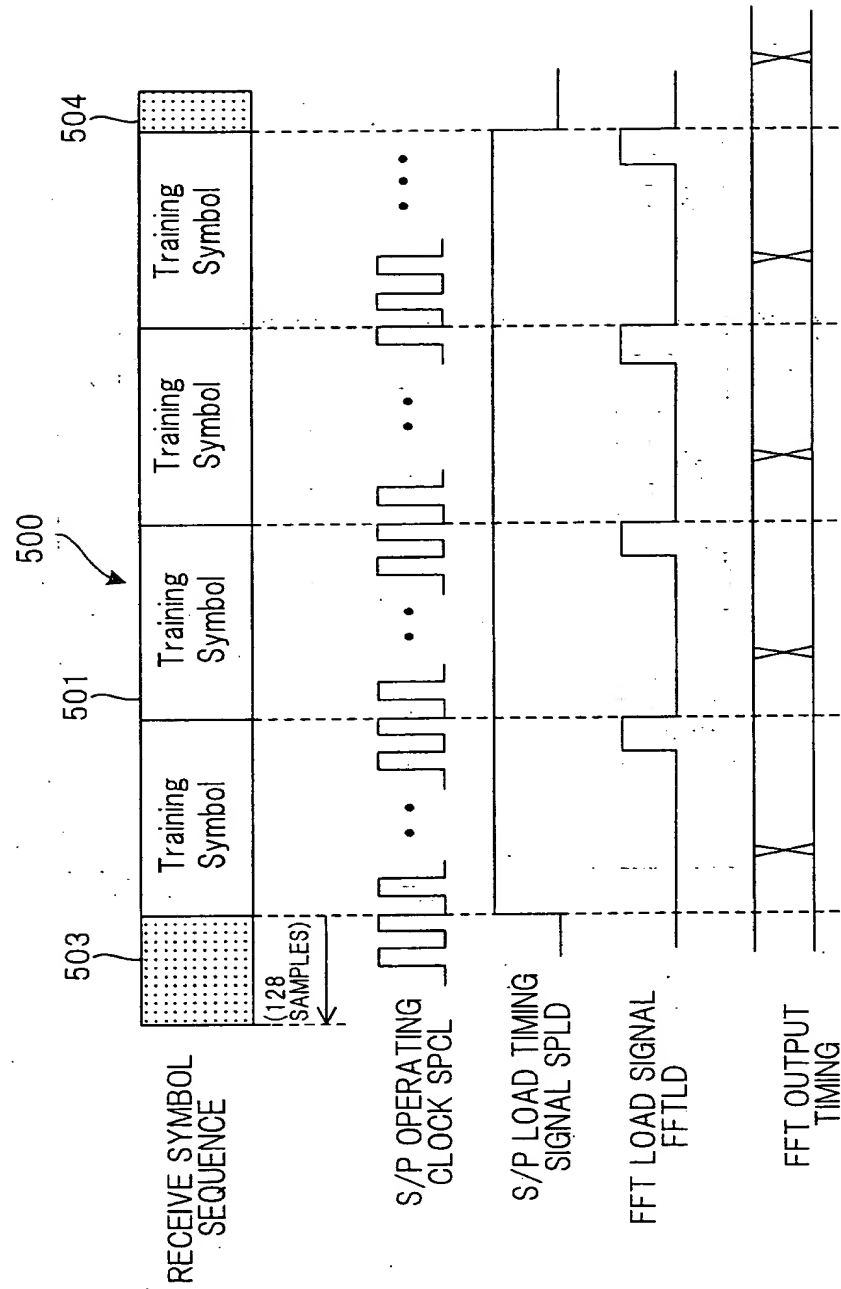


FIG. 16

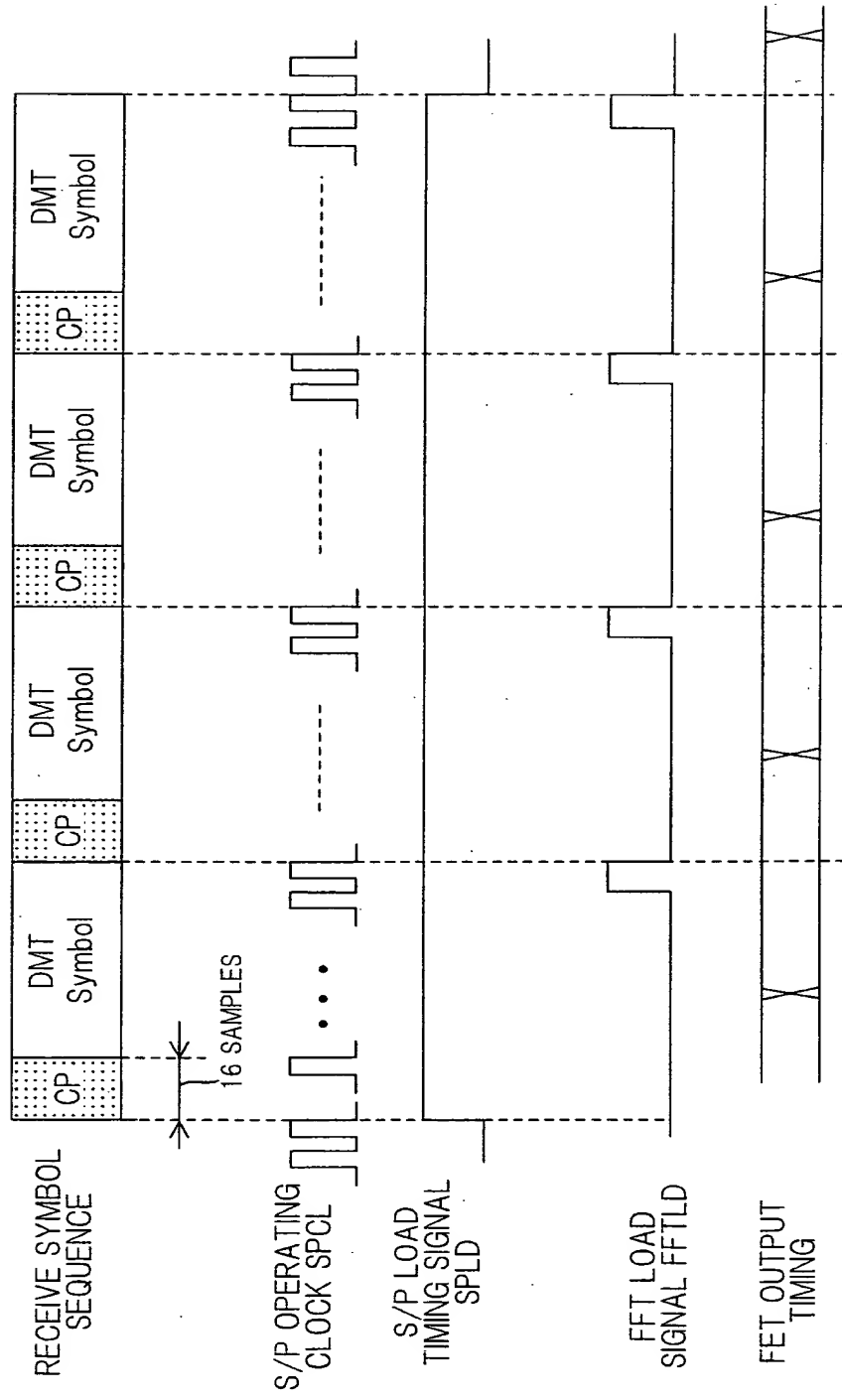


FIG. 18

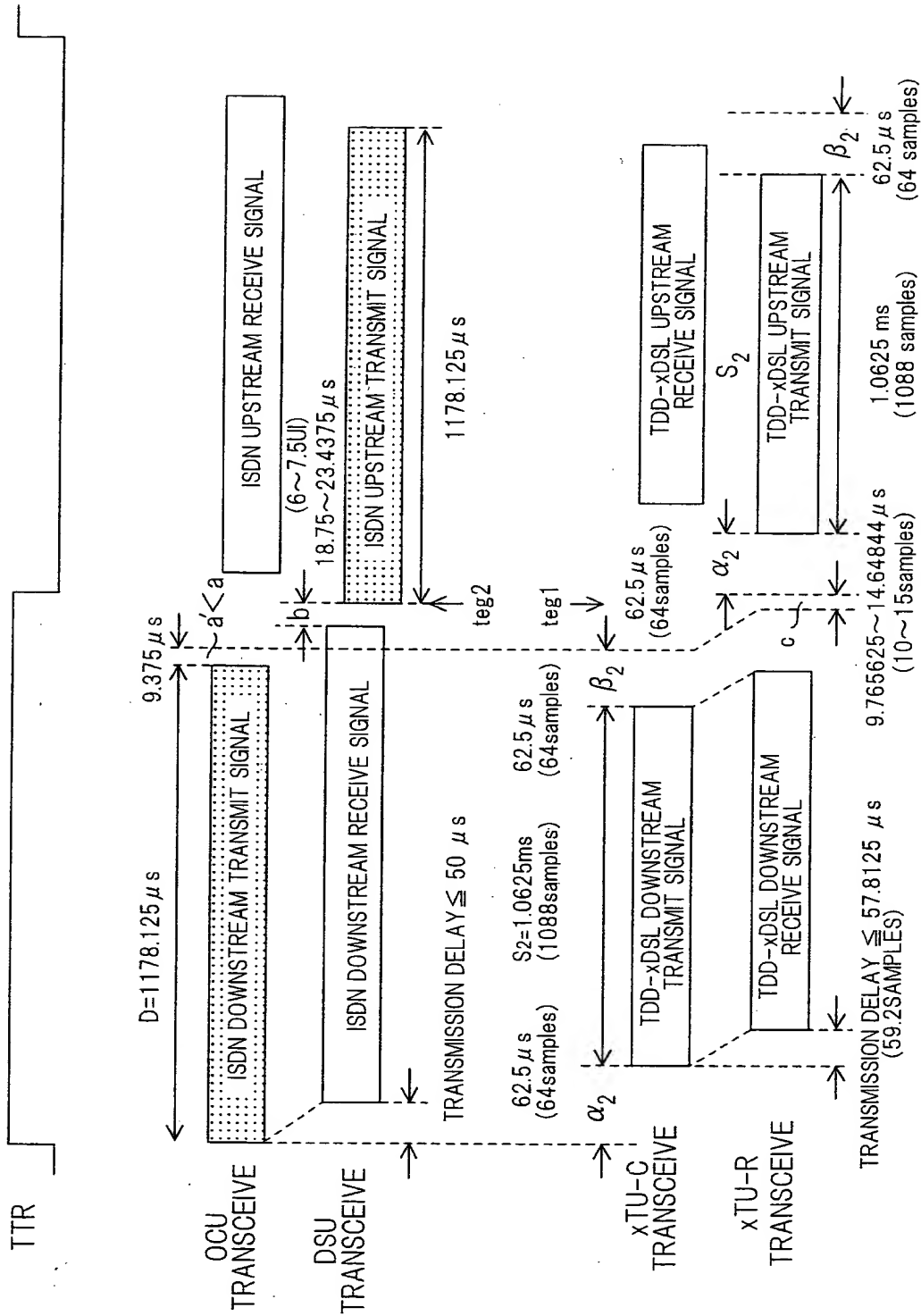


FIG. 19

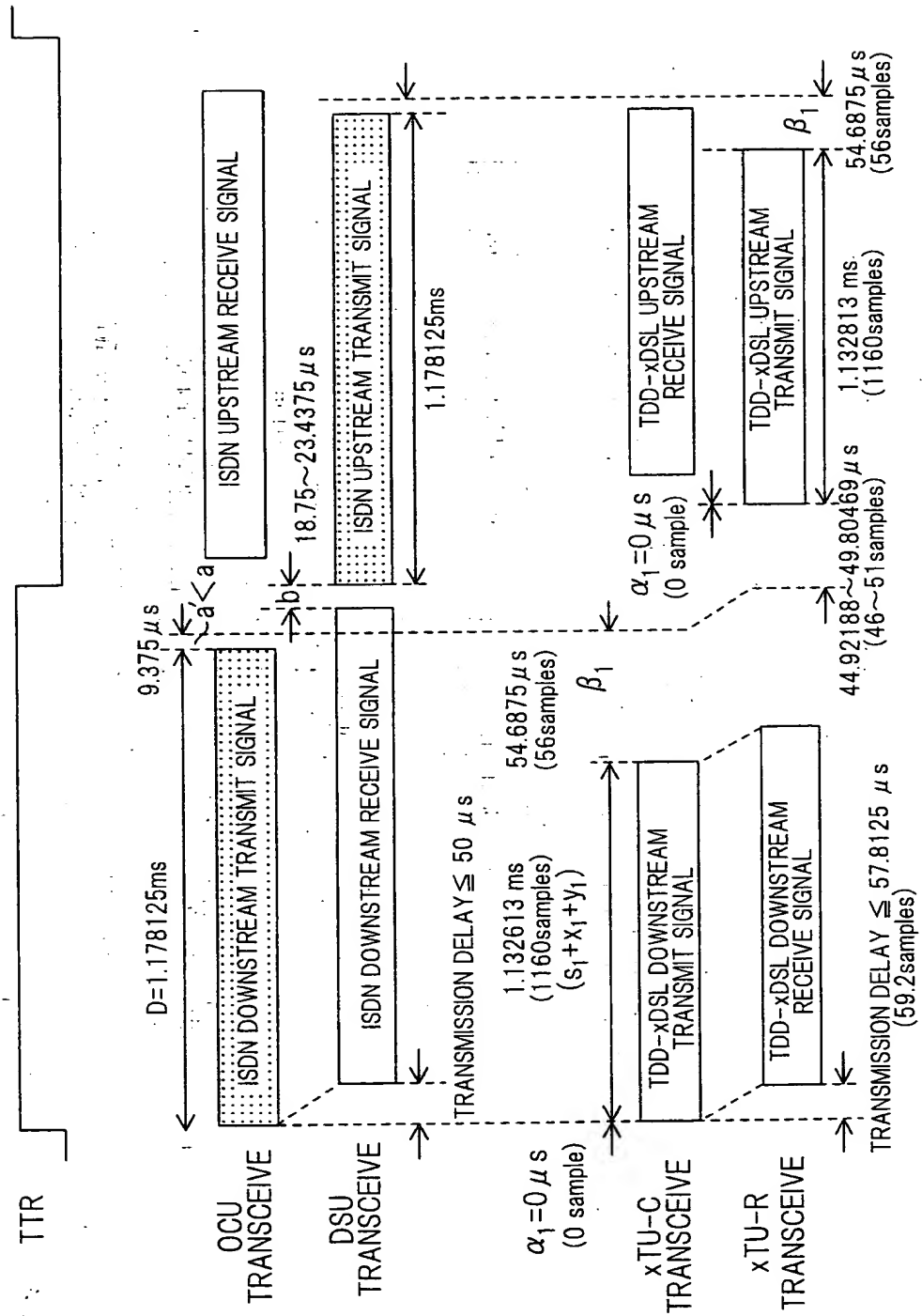


FIG. 20

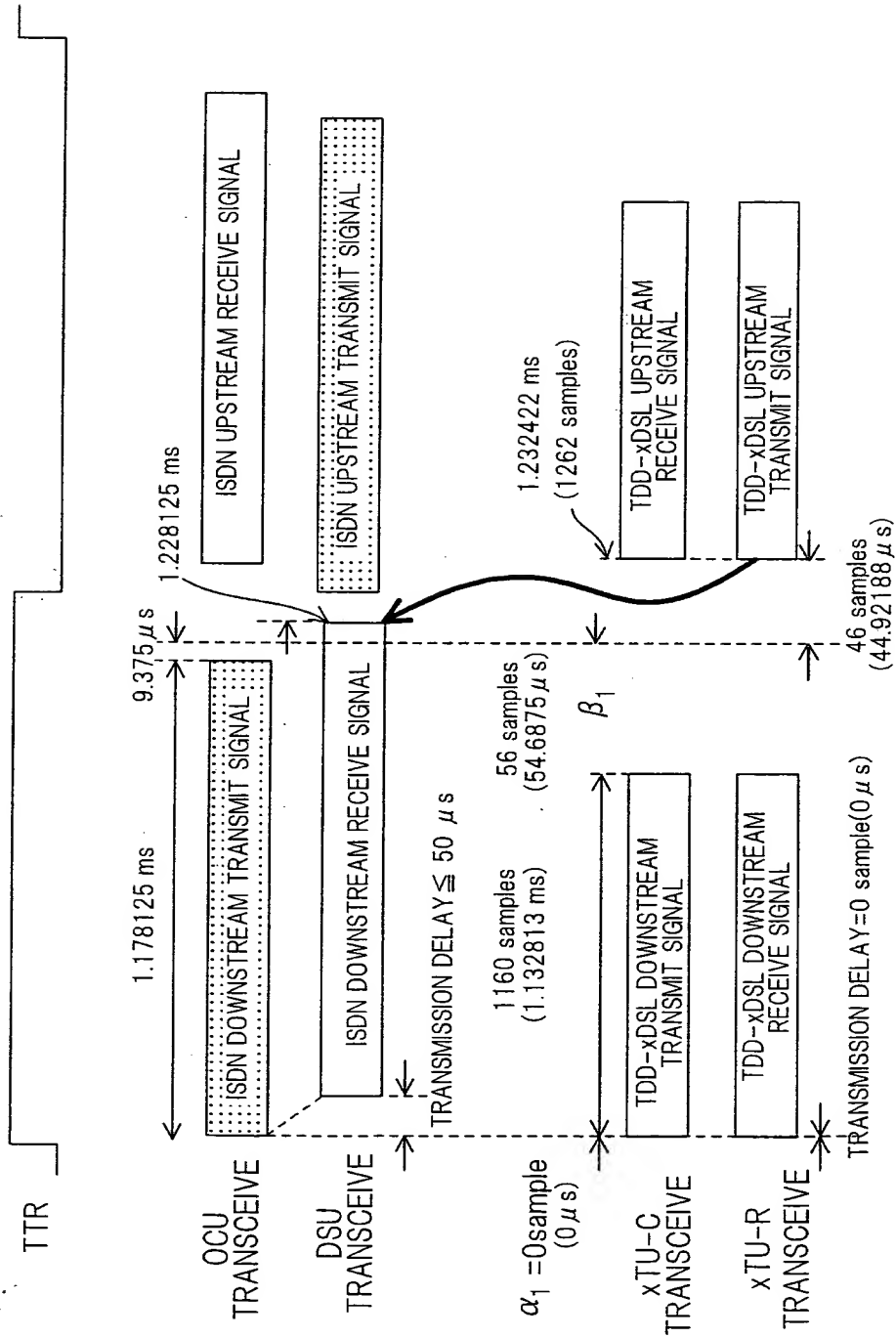


FIG. 21

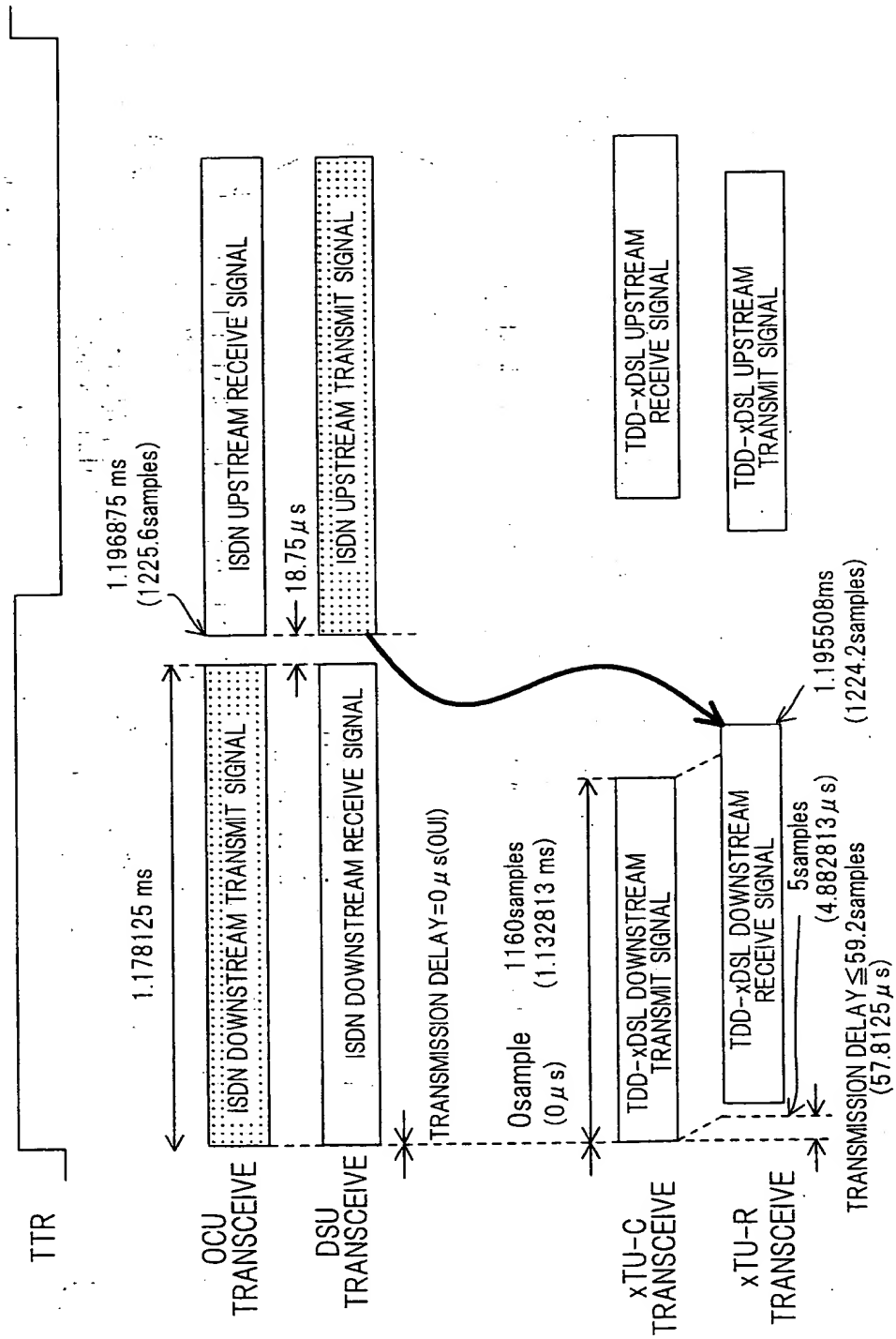


FIG. 22

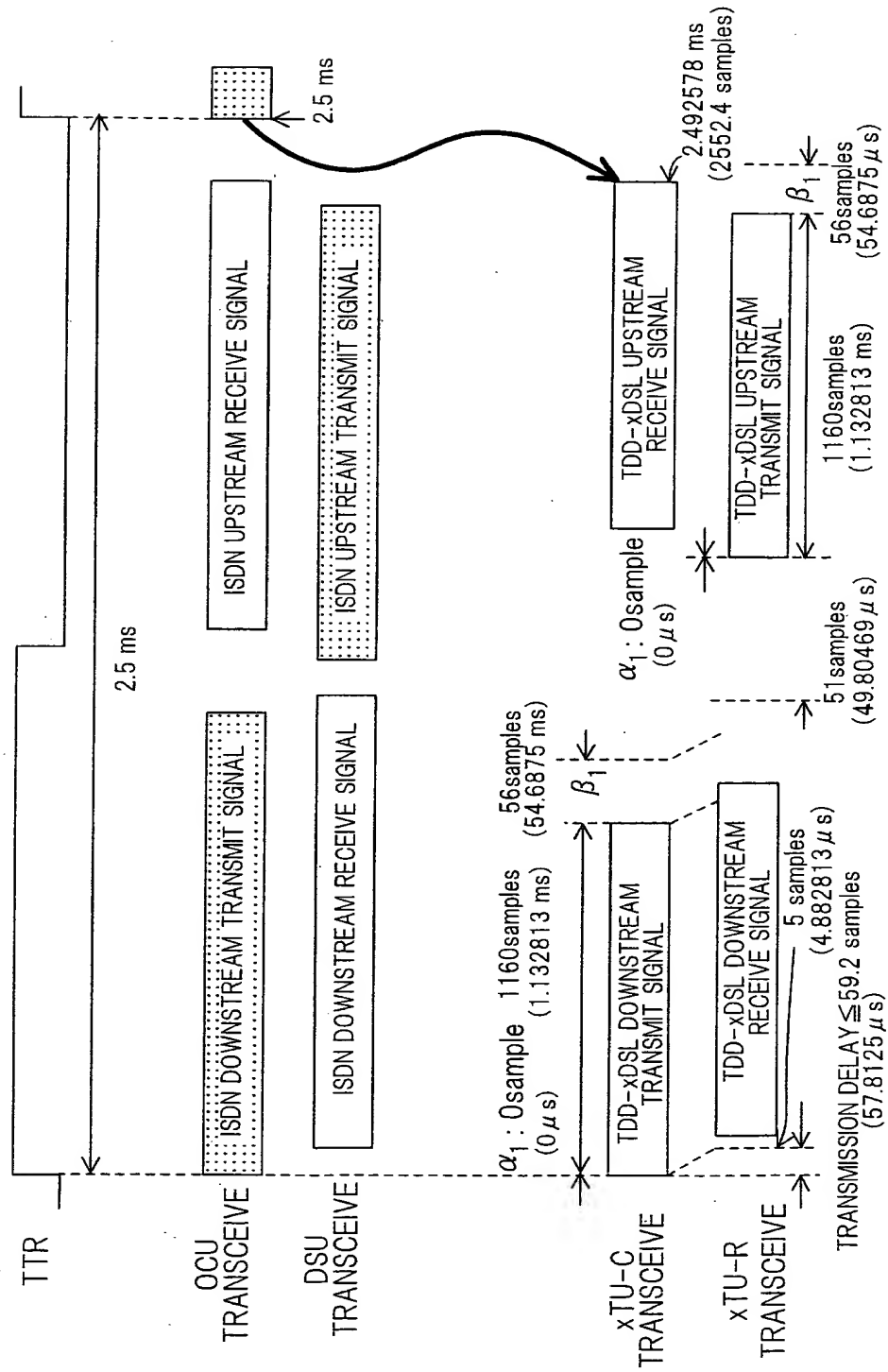
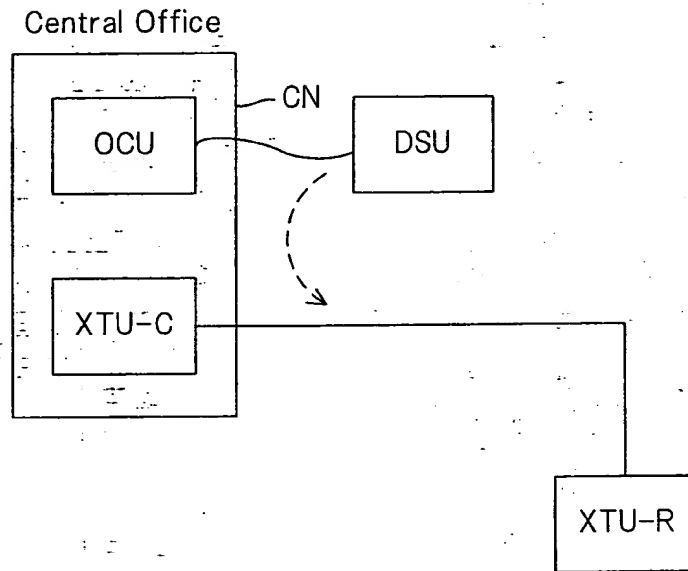


FIG. 23

- (a) IN CASE WHERE ISDN LINE DELAY IS SMALL
AND TDD-xDSL LINE DELAY IS LARGE



- (b) IN CASE WHERE ISDN LINE DELAY IS LARGE
AND TDD-xDSL LINE DELAY IS SMALL

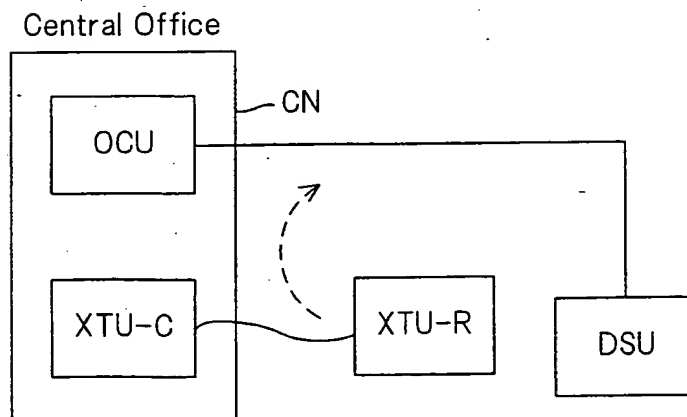


FIG. 24

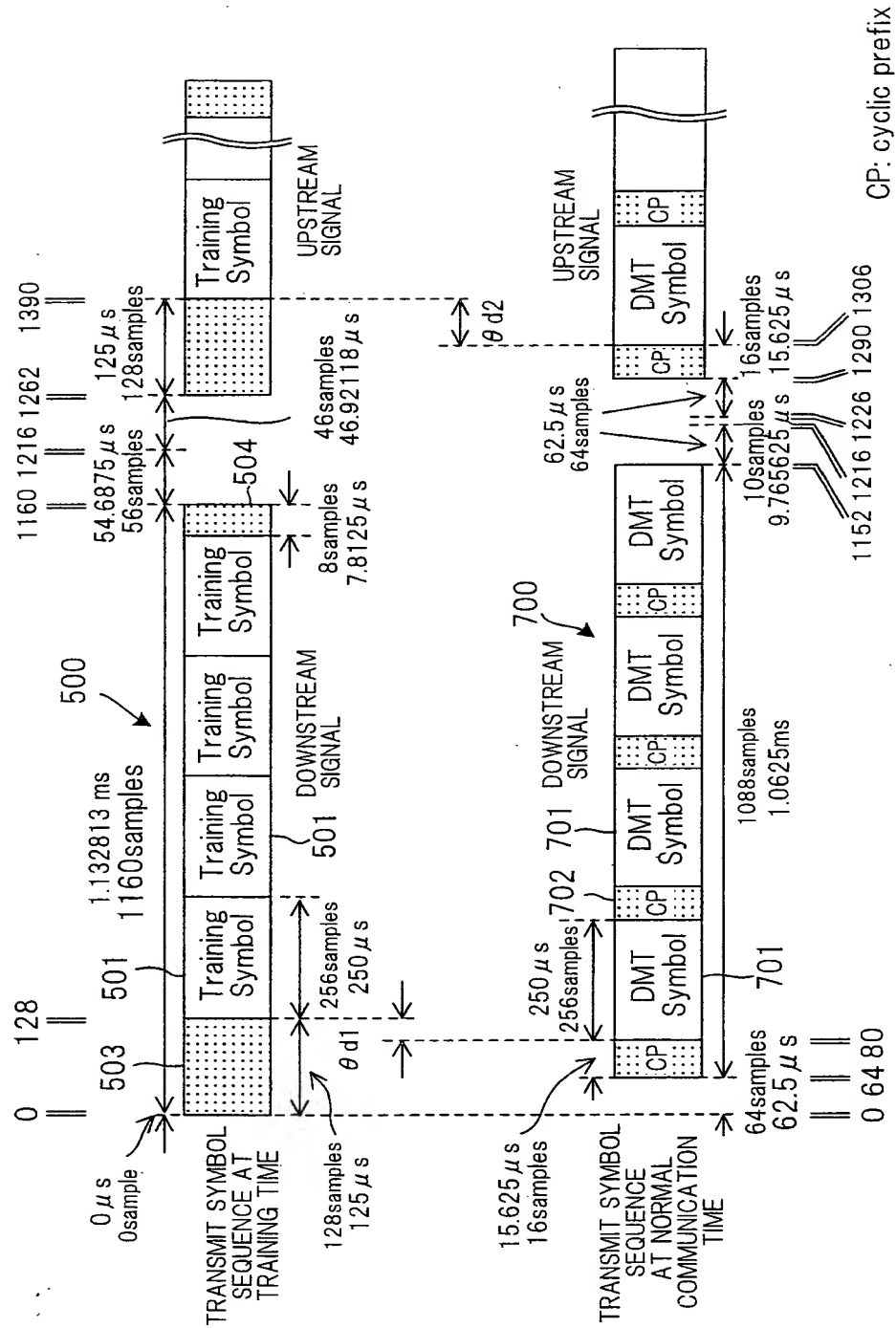


FIG. 26

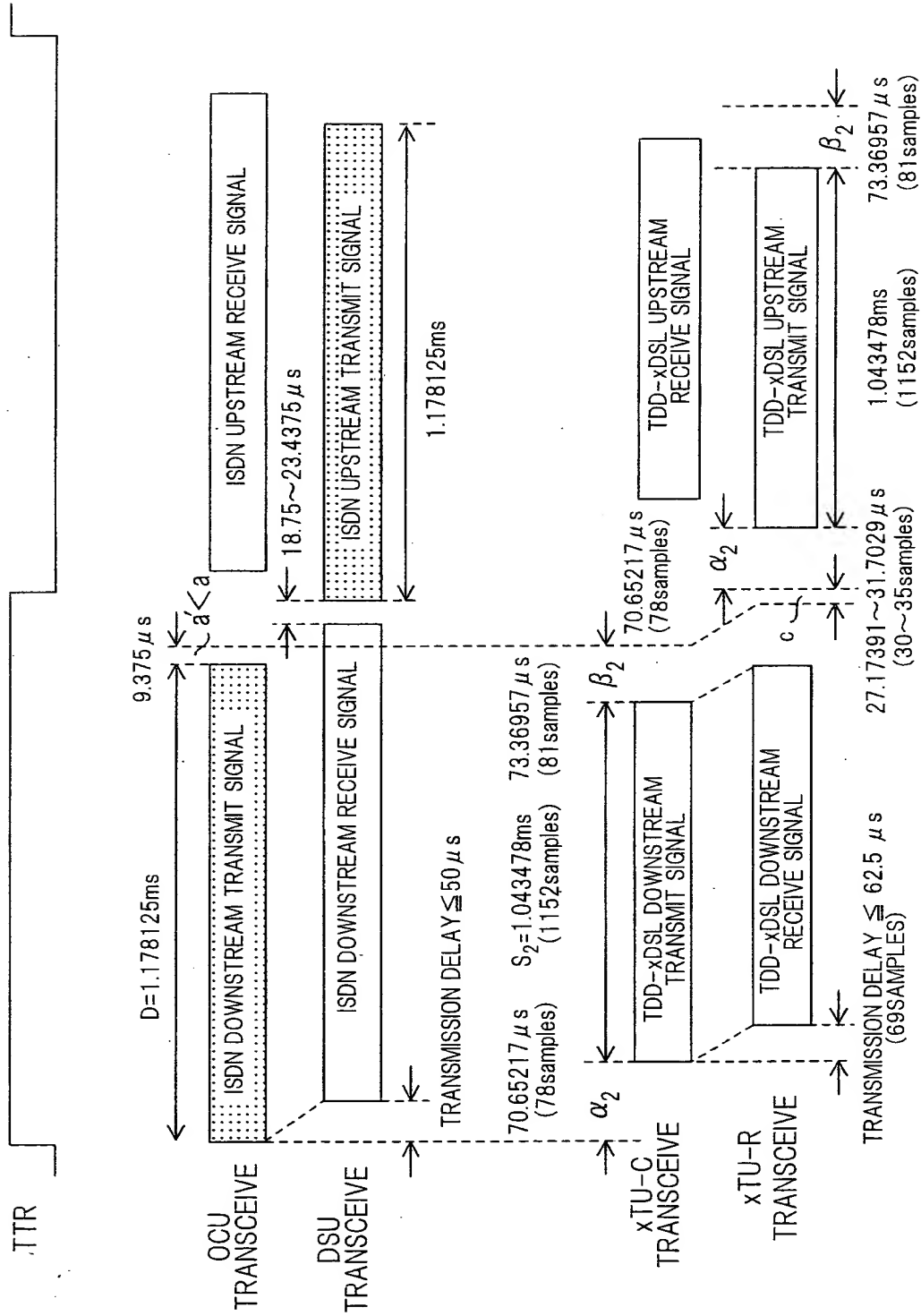


FIG. 27

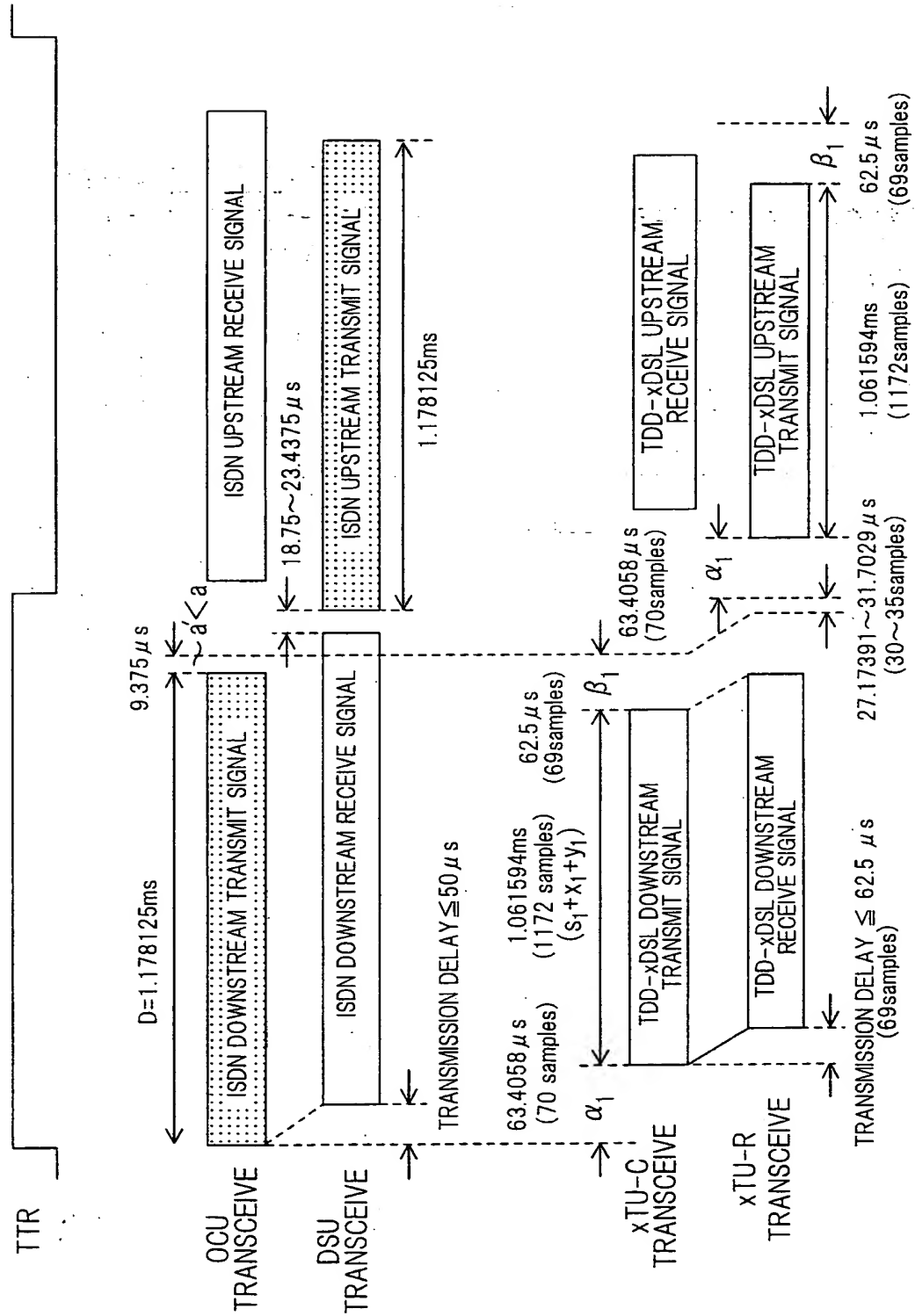


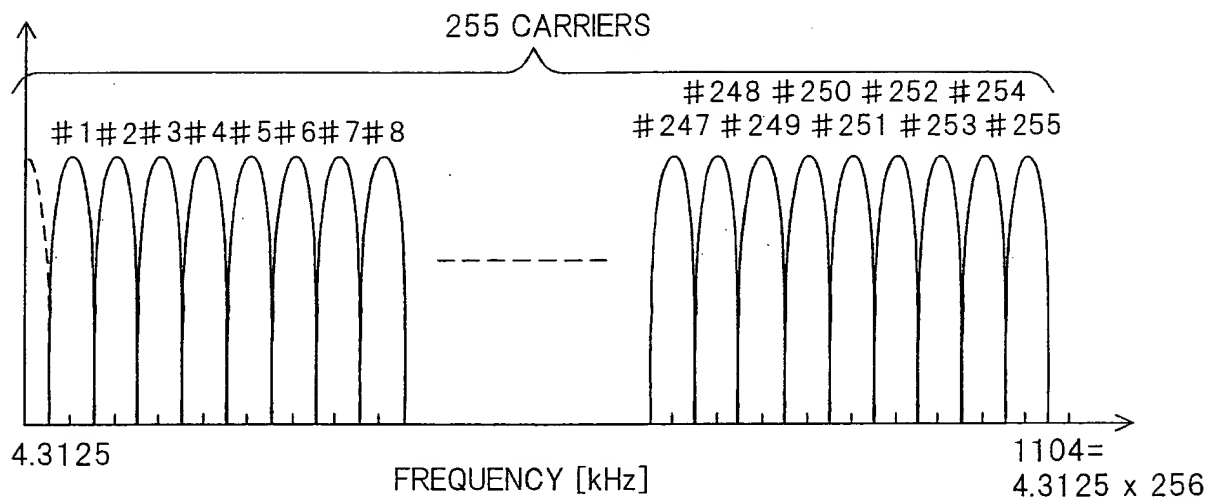
FIG. 28

FIG. 29

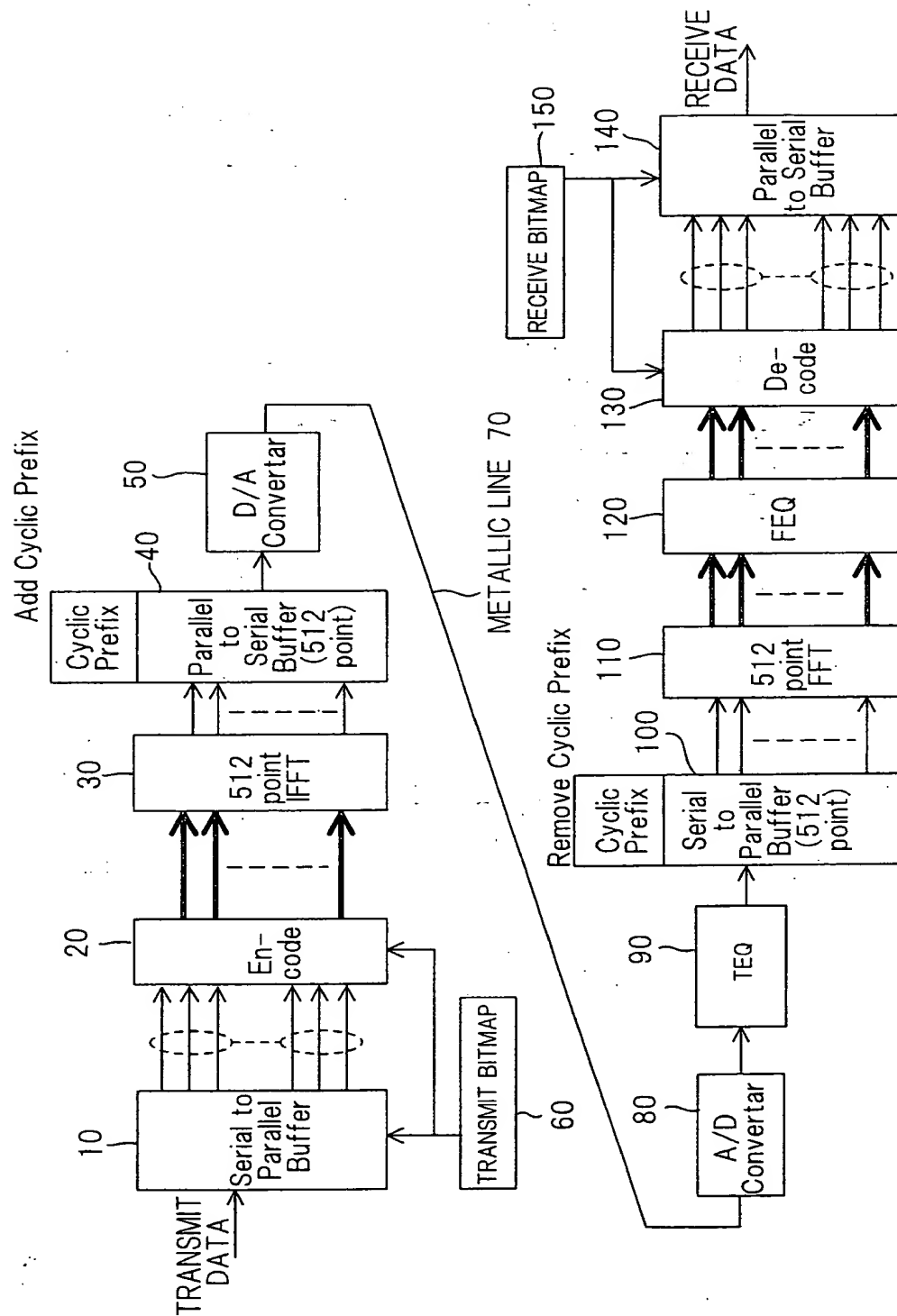


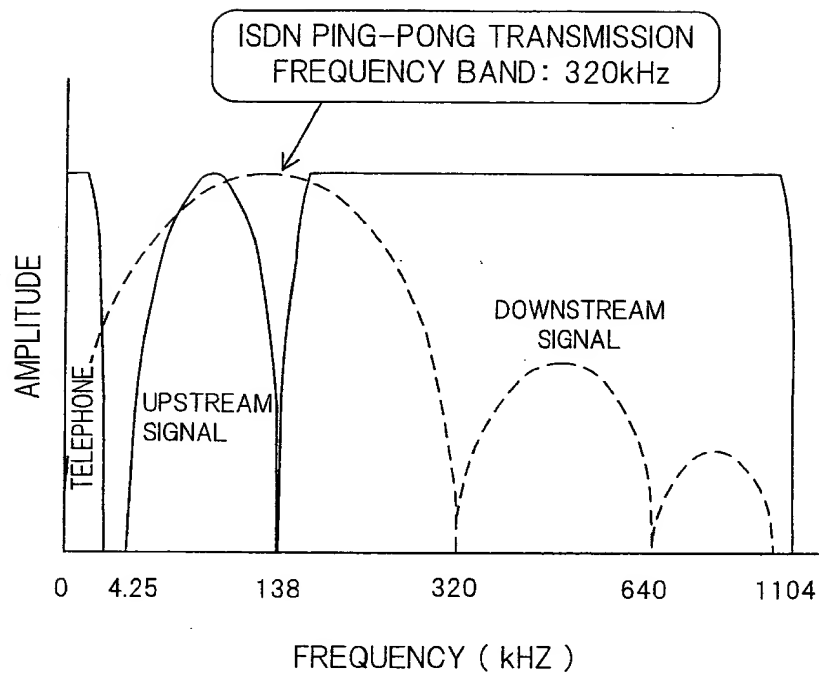
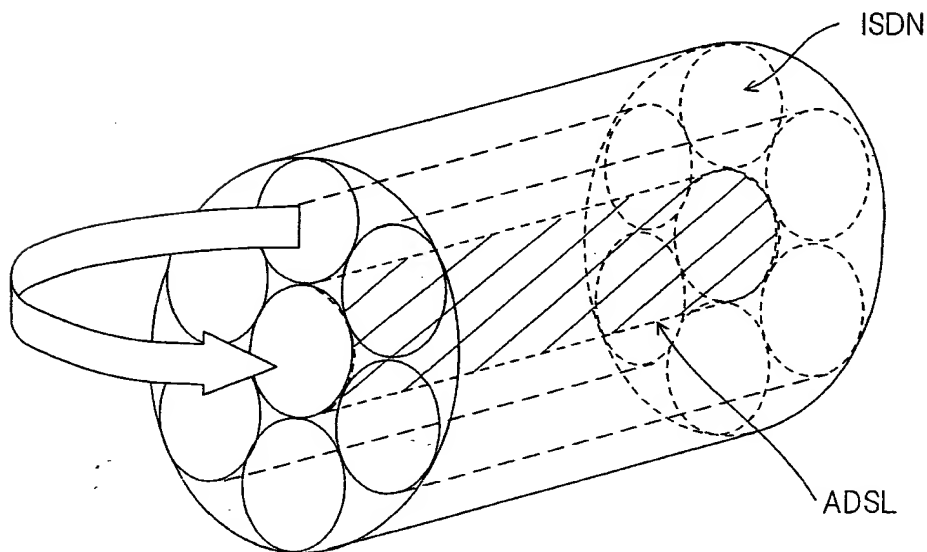
FIG. 30**FIG. 31**

FIG. 32

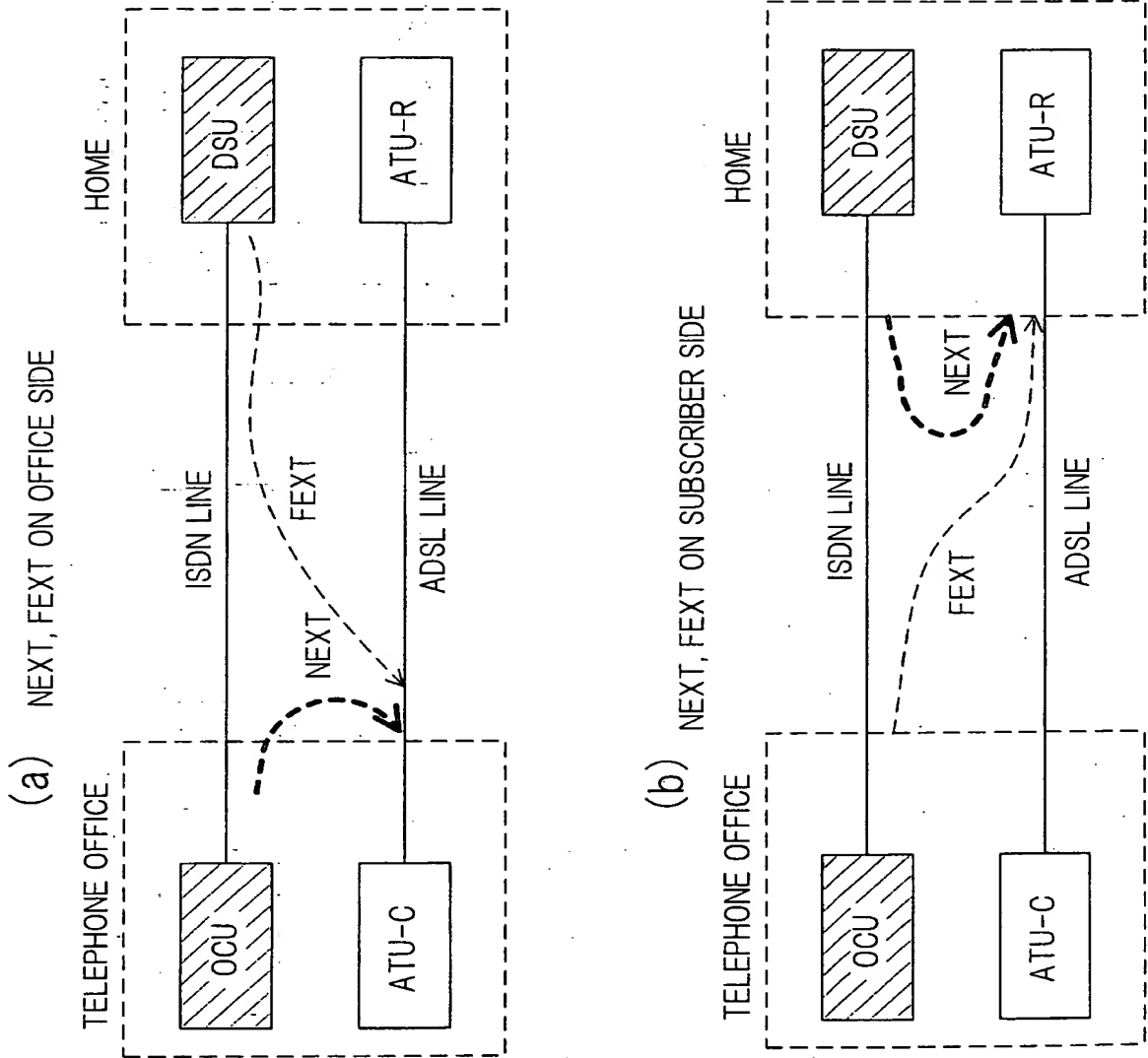


FIG. 33

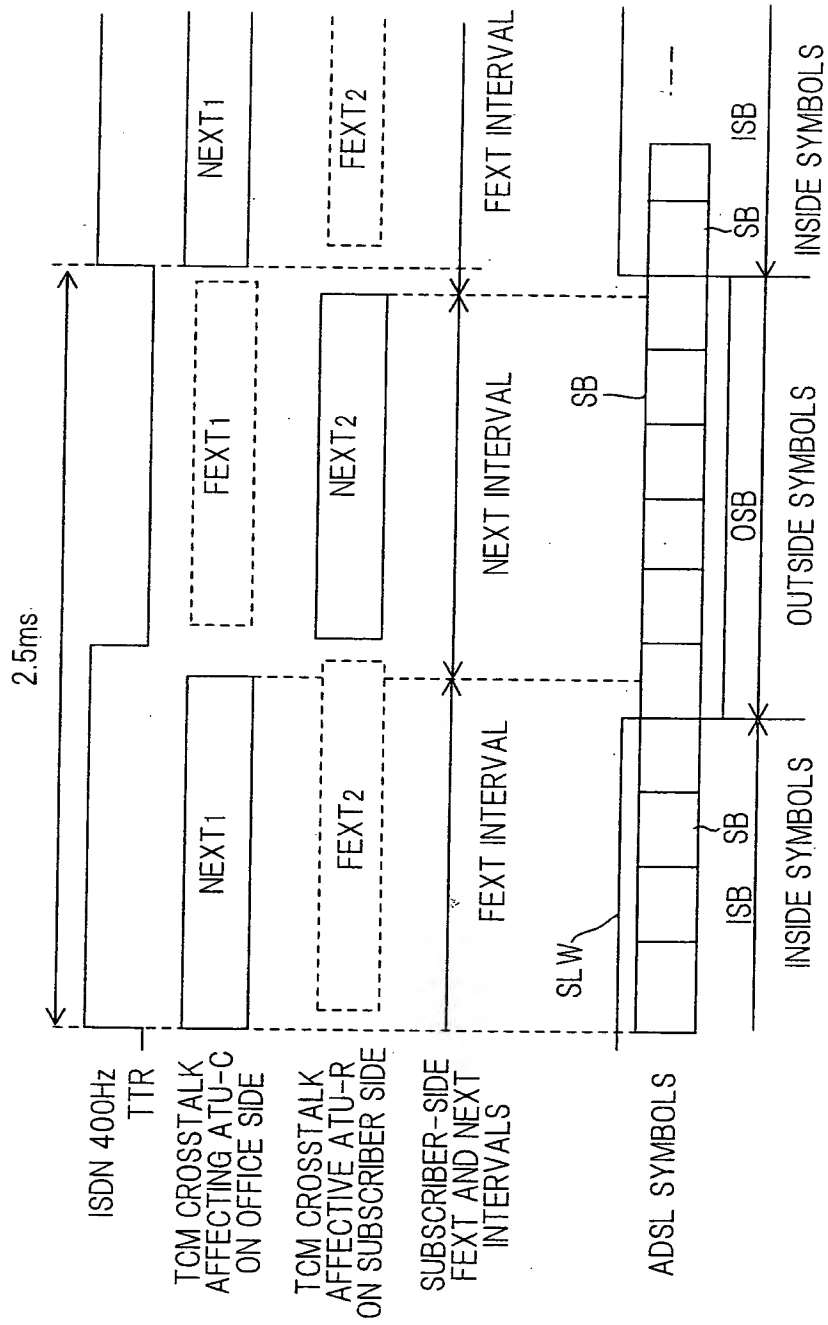


FIG. 34

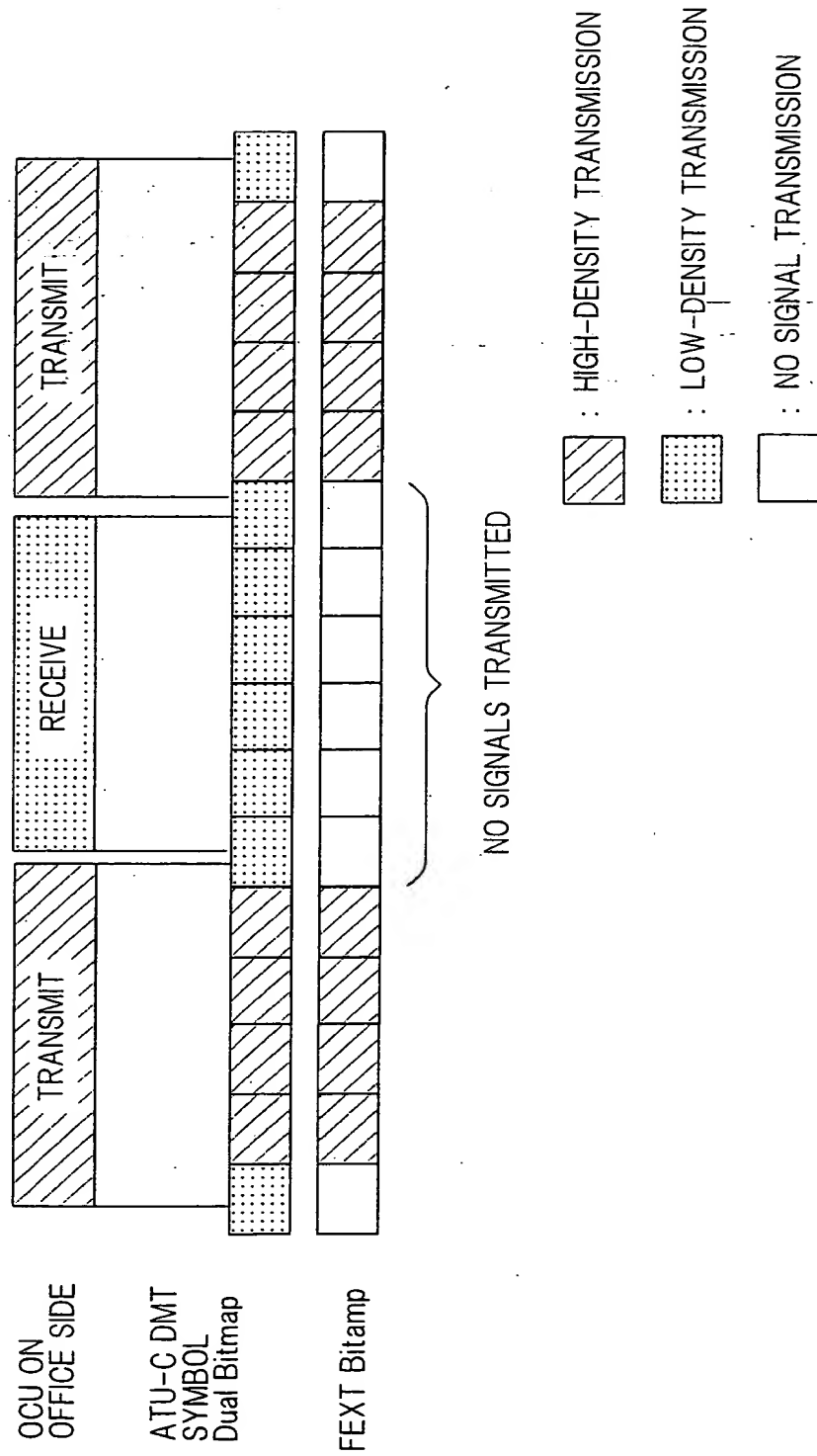


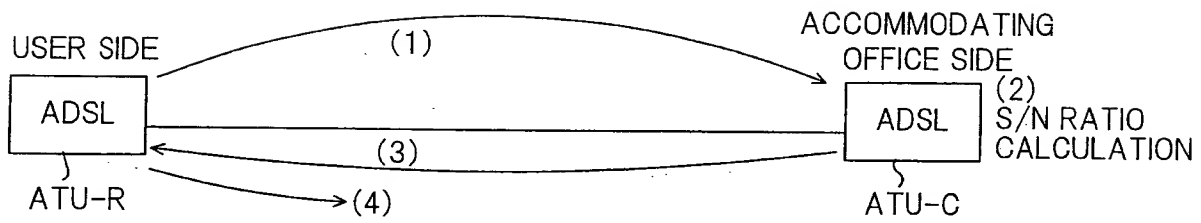
FIG. 35

FIG. 36

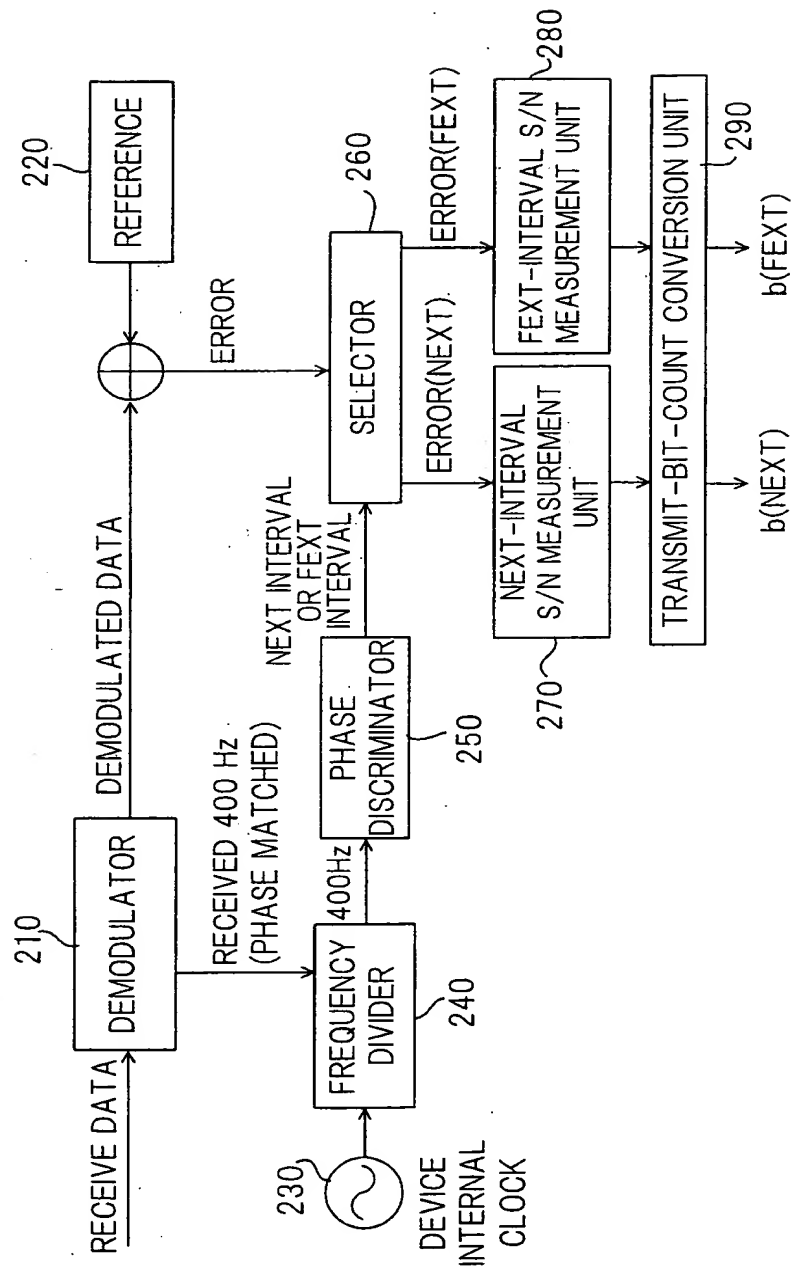


FIG. 38

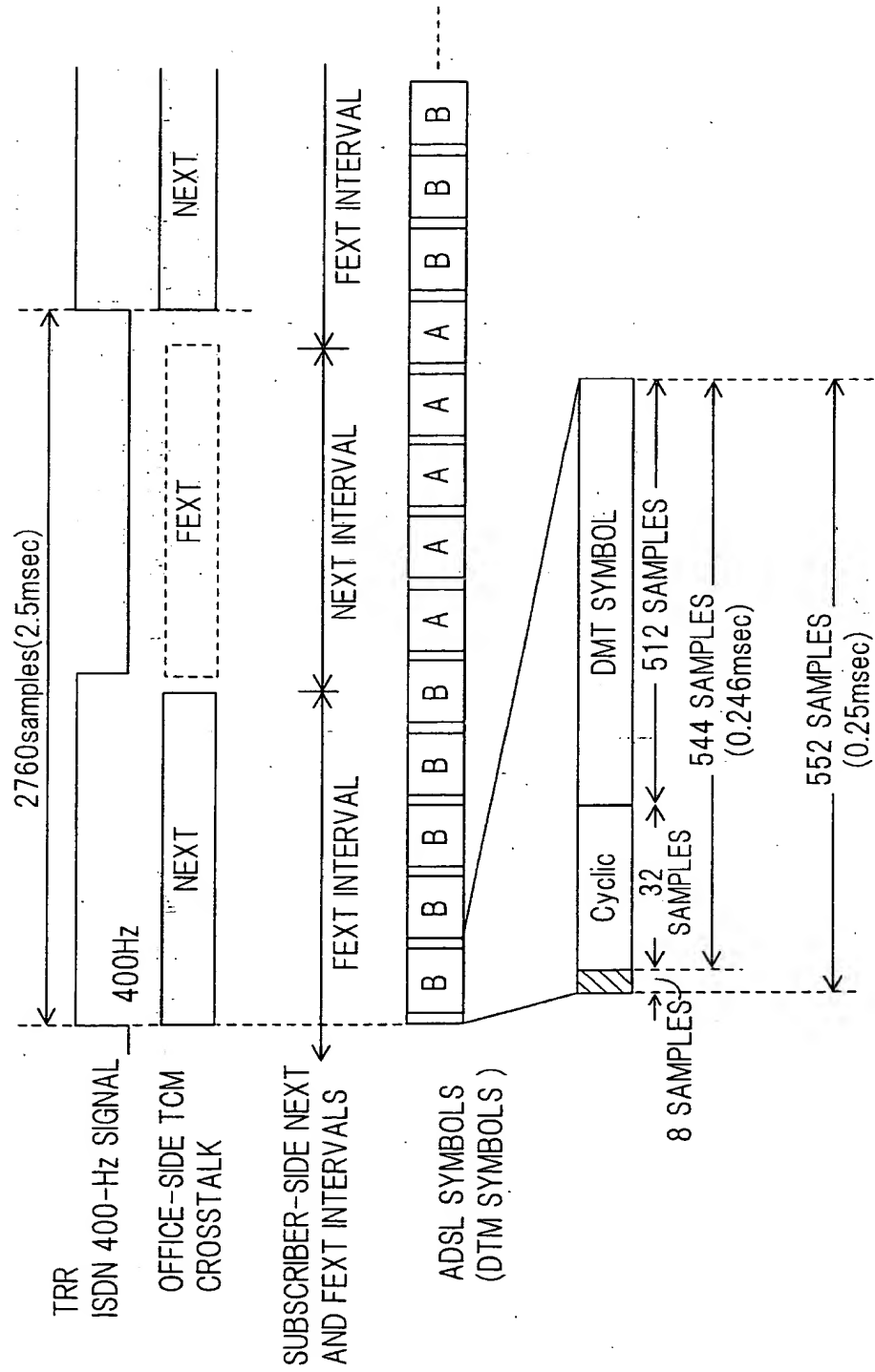


FIG. 39

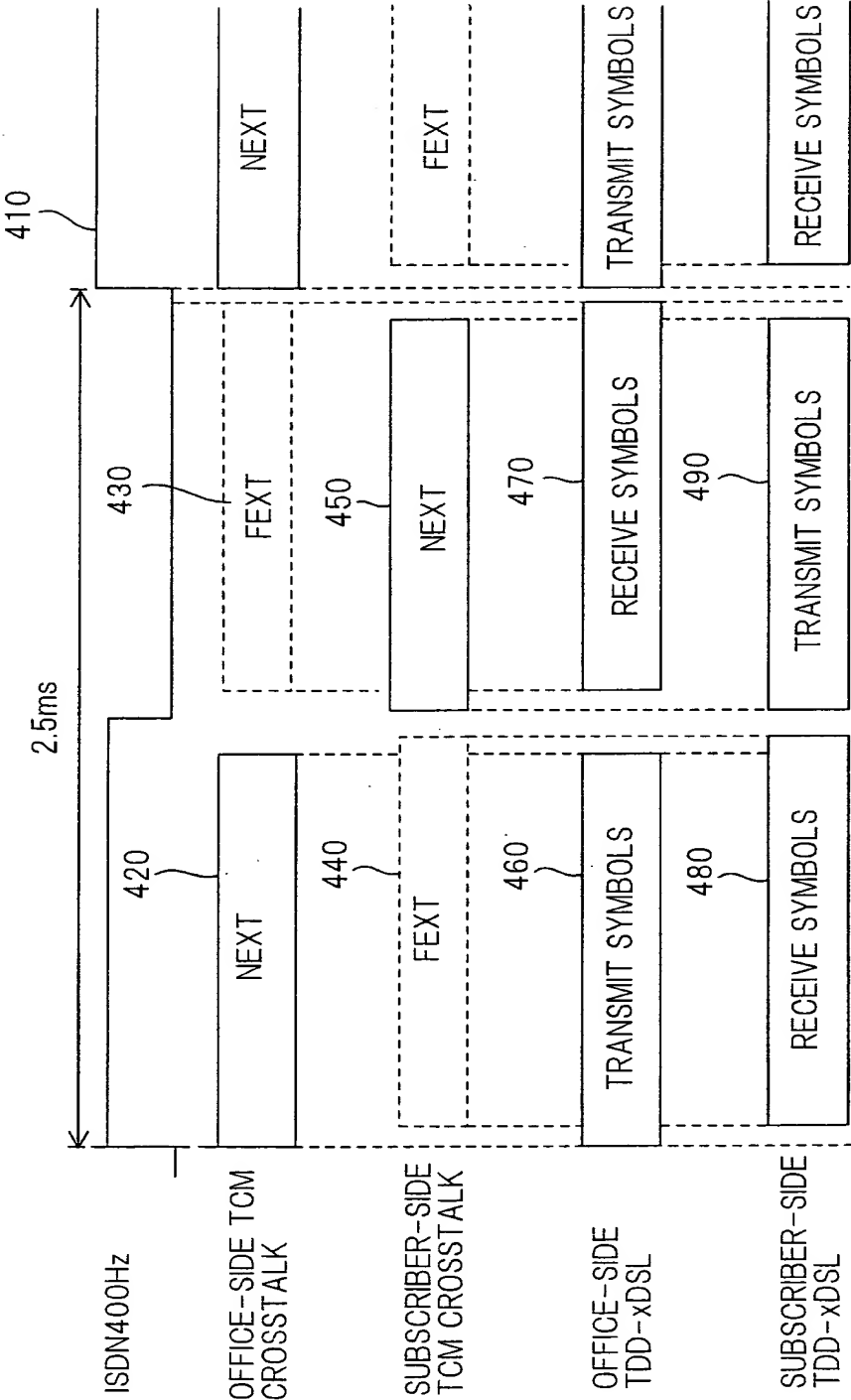


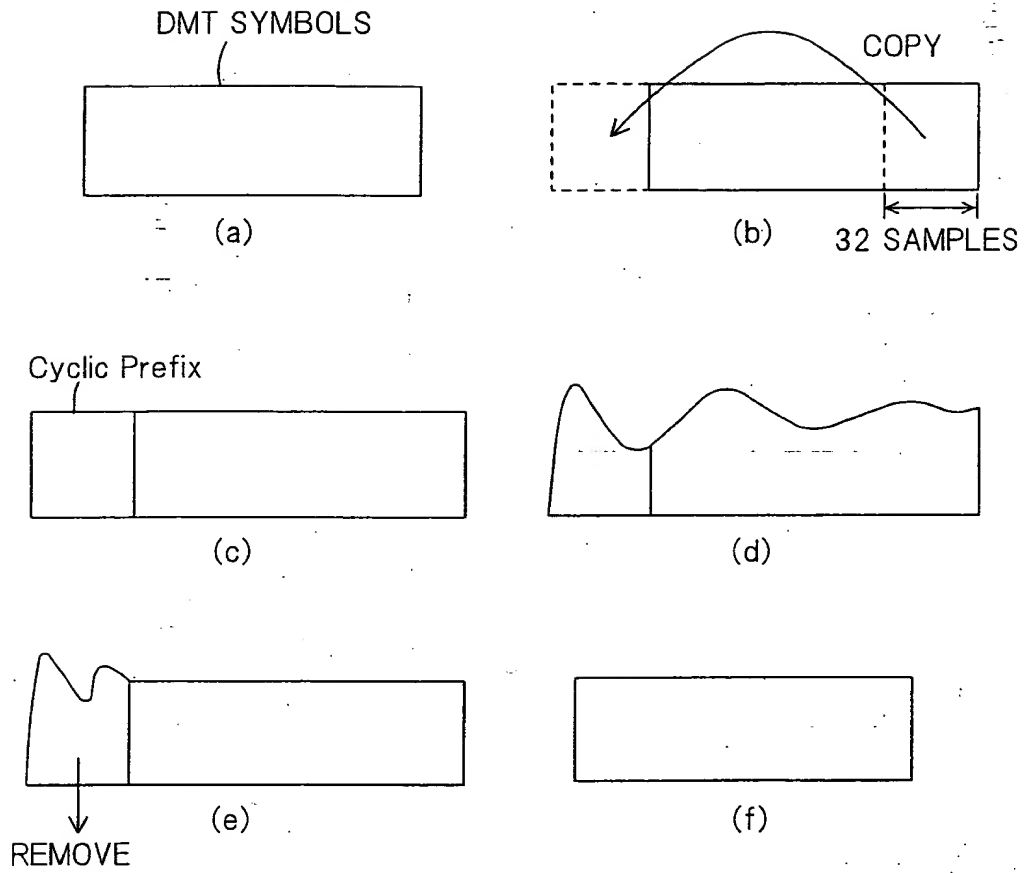
FIG. 40

FIG. 41

